Fact or Fiction

Science Tackles 58 Popular Myths

SCIENTIFIC AMERICAN

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From the Editors of Scientific American

Letters to the Editor

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Stranger Than Fiction

"Truth is stranger than Fiction, but it is because Fiction is obliged to stick to possibilities; Truth isn't." –Mark Twain

The mythology of our everyday lives is often startlingly convincing. Folk knowledge, old wives' tales and urban legends have the power of the populace behind them—the *could-all-those-people-be-wrong* effect. (Answer: yes, they can.) Then, some stories are so outlandish that their very incredibleness makes them seem credible—the *how-could-anyone-have-made-that-up* effect. (Answer: with some imagination.) Whatever the reason, that human beings will suspend disbelief to admit the possibility of the strange and extraordinary is one of our best traits as a species. That we sometimes fail to check our source material, not so much.

Enter *Scientific American*'s "Fact or Fiction?" and "Strange But True" columns. Like *Mythbusters* and snopes.com, these short, entertaining columns are dedicated to revealing the veracity and the mendacity in common lore. This eBook, *Fact or Fiction: Science Tackles 58 Popular Myths*, presents a sampling of the surprising, fascinating, useful and just plain wacky topics discussed by our writers over the years. We uncover the truth behind common myths from personal health (you can put down those vitamins and that extra glass of water) to zany animals (think zombie cockroaches) to a NASA pen only Bill Gates can afford.

Section One, "The Animal Kingdom," examines the intricacies and amazing qualities of our fellow earthly inhabitants. Virgin births can happen outside of the Bible and squid have a superpower. Whale waste might not be as shiny as gold, but it is similarly valuable. And no, your dog should not eat your leftover Valentine chocolate.

In "Babies and Parents," the writers advise as to whether or not you should buy *The Complete Mozart* for your yet-to-be baby and whether or not Dad can help out with the breast-feeding. The sections "Health Habits," "The Body" and "Mind and Brain" explore just how much of our common conceptions surrounding our selves and well-being are based in fact or…aren't. You should not, for example, pee on jellyfish stings, as that will make the situation simultaneously more painful and more disgusting.

Its inhabitants are enthralling, but Earth and the universe have their own quirks, as shown in "The Environment: Earth and Space." This section looks at whether toilets really do flush in the opposite direction south of the Equator and whether black holes sing (and do they take requests). Finally, in "Miscellany" we present some pieces perfect for upping your *Trivial Pursuit* knowledge.

Science is defined by *Merriam-Webster* as "a system of knowledge covering general truths," and we at *Scientific American* are constantly trying to separate fact from fiction in *all* topics, be it quantum mechanics or chewing gum digestion. This eBook is only a fraction of our publication's continuous search for truth. But we hope it's an enjoyable fraction and encourages you to do some myth busting yourself.

-Hannah Schmidt

Book Editor

SECTION 1

The Animal Kingdom

Chocolate Is Poisonous to Dogs

by Alison Snyder

A small dog should be belly-up after eating a handful M&M's, at least according to conventional wisdom. But watching "Moose," a friend's five-pound Chihuahua, race around a living room after his sweet snack makes one wonder: Is chocolate truly poisonous to dogs?

Dogs and humans have similar tastes. Like us, they seek out sweets and have no problem indulging. But unlike humans, our canine companions experience dangerous effects from eating chocolate—it can poison them and in some cases is lethal. The hazard, however, is probably overblown, says Tim Hackett, a veterinarian at Colorado State University. Chocolate's danger to dogs depends on its quantity and quality. Large dogs can usually handle a small amount of chocolate whereas the same helping could cause problems for Moose and his pint-size kin.

Chocolate is processed from the bitter seeds of the cacao tree, which contain a family of compounds known as methylxanthines. This class of substances includes caffeine and the related chemical theobromine. Both molecules bind to receptors on the surfaces of cells and block the natural compounds that normally attach there. Low doses of methylxanthines can lead to vomiting or diarrhea in dogs, and euphoria in humans. Chocolate contains a significant amount of theobromine and smaller amounts of caffeine. If a large quantity of theobromine or caffeine is ingested, some dogs will experience muscle tremors or even seizures. These chemical constituents of chocolate can cause a dog's heart to race up to twice its normal rate, and some dogs may run around as if "they drank a gallon of espresso," according to Hackett. Moose, it seems, was on a "theobromine high."

Dogs are capable of handling some chocolate, but it depends on the animal's weight and the type of chocolate it eats. Unsweetened baking chocolate contains more than six times as much theobromine as milk chocolate, although amounts vary between cocoa beans as well as different brands of chocolate. Less than four ounces of milk chocolate is potentially lethal for Moose and other small dogs, according to the ASPCA Animal Control Poison Center.

Around every confection-centered holiday—Valentine's Day, Easter and Christmas—at least three or four dogs are hospitalized overnight in the animal medical center at Colorado State. But in 16 years as an emergency and critical care veterinarian, Hackett has seen just one dog die from chocolate poisoning, and he suspects it may have had an underlying disease that made it more vulnerable to chocolate's heart-racing effect.

Dogs that eat a small amount of chocolate should be able to filter the methylxanthines through their body and avoid veterinary treatment. But more acutely poisoned dogs are generally treated by inducing vomiting and administering activated charcoal to absorb any methylxanthines remaining in the gut or that may be circulating through the dog's digestive system

Ultimately, Moose survived his cocoa snack. But no matter how you bake it, wrap it or melt it, chocolate and Moose don't mix.

--Originally published: Scientific American Online, February 2, 2007.

Komodo Dragons Show That Virgin Births Are Possible

by Philip Yam

Indonesian dragons can breed without the benefit of masculine companionship. Researchers reported in Nature that the only two sexually mature female Komodo dragons in all of Europe laid viable eggs without insemination from a male. One Komodo, named Flora, lives at the Chester Zoo in England and has never been kept with a male; yet in 2006 she laid a clutch of 11 eggs, eight of which survived and are now settled in zoos around the world. Earlier in 2006, a now deceased female named Sungai from the London Zoo laid a clutch of 22 eggs, four of which yielded normal male dragons--even though Sungai hadn't had a date in two and a half years.

Some reptiles can hold onto sperm for several years, so initially researchers considered that Sungai's eggs had a father. But genetic analysis ruled that out, unless the father were somehow genetically identical to her. (Sungai did later mate with a male and laid a normally fertilized clutch, so don't think she died a virgin.)

These "virgin births" raised eyebrows because this asexual method of reproduction, called parthenogenesis, is rare among vertebrates: only about 70 backboned species can do it (that's about 0.1 percent of all vertebrates). Biologists have known that some lizards can engage in parthenogenesis, but nonetheless seeing it among Komodo dragons surprised zookeepers.

Despite having only a mother, the offspring are not clones. That's because an unfertilized egg has only half the genes of the mother. The sperm is supposed to provide the other half. In parthenogenesis, the mother's half-set of chromosomes doubles up to generate the full complement. Hence, the offspring derives all its genes from the mother, but they are not a duplicate of her genome.

Komodos have a curious twist in their sex determination as well. Although we think of females being XX (that is, having two X chromosomes) and males as being XY, it's the other way around in these giant monitor lizards. Two identical sex chromosomes make a male Komodo, and two different ones make a female. Biologists label the Komodo's sex chromosomes as W and Z, so ZZ makes a male and WZ makes a female. Birds, some insects and a few other lizard species also rely on this sex-determination system. (Embryos of some reptiles--notably crocodiles and turtles--don't have any sex chromosomes; rather, the incubation temperature dictates their gender.)

In Komodo females, each egg contains either a W or a Z. Parthenogenesis hence leads to embryos that are either WW or ZZ. Eggs that consist of WW material are not viable and die off (just as YY is not a viable combination); in contrast, ZZ does work. So all the Komodo hatchlings have been and will be male (ZZ).

Evidently, in the case of these Komodos, the doubling of the egg genes occurred when, in essence, another egg, rather than sperm, did the job of fertilization. Oogenesis, the biological process of making an egg cell, typically also yields a polar body--a mini ovum of sorts, containing a duplicate copy of egg DNA. Normally, this polar body shrivels up and disappears. In the case of the Komodos, though, polar bodies evidently acted as sperm and turned ova into embryos.

The ability to reproduce both sexually and parthenogenetically probably resulted from the Komodo

dragon's isolated natural habitat, living as it does on islands in the Indonesian archipelago. Researchers have seen other species resort to parthenogenesis when isolated, such as damselflies in the Azores. The ability, researchers speculate, may have enabled the dragons to establish new colonies if females had found themselves washed up alone on neighboring shores, as might happen during a storm.

High school biology texts tend to gloss over parthenogenesis, typically mentioning the process as rare and restricted to mostly small invertebrates. But the phenomenon has emerged from the backwaters in recent years, primarily as a tool for science. Some scientists hope to exploit the phenomenon to get around ethical concerns surrounding embryonic stem cell research. They can fool an unfertilized human egg to divide by pricking it, thereby simulating the penetration of sperm. Such deceived eggs continue dividing into the blastocyst stage of 50 to 100 cells before petering out naturally.

In principle, it may be possible to keep that cell dividing. In 2004, as a means to elucidate the details of how fertilized eggs develop, scientists in Japan engaged in some genetic trickery to create a fatherless mouse. Such a developmental process probably didn't happen in the little town of Bethlehem two millennia ago--the mistranslation of "young girl or maid" into "virgin" explains the story a lot better. But as the Komodo dragons' astonishing parthenogenesis feat shows, nature has plenty to teach us about making do without a mate.

--Originally published: Scientific American Online December 28, 2006.

A Cockroach Can Live without Its Head

by Charles Q. Choi

Cockroaches are infamous for their tenacity, and are often cited as the most likely survivors of a nuclear war. Some even claim that they can live without their heads. It turns out that these armchair exterminators (and their professional brethren) are right. Headless roaches are capable of living for weeks.

To understand why cockroaches—and many other insects—can survive decapitation, it helps to understand why humans cannot, explains physiologist and biochemist Joseph Kunkel at the University of Massachusetts Amherst, who studies cockroach development. First off, decapitation in humans results in blood loss and a drop in blood pressure hampering transport of oxygen and nutrition to vital tissues. "You'd bleed to death," Kunkel notes.

In addition, humans breathe through their mouth or nose and the brain controls that critical function, so breathing would stop. Moreover, the human body cannot eat without the head, ensuring a swift death from starvation should it survive the other ill effects of head loss.

But cockroaches do not have blood pressure the way people do. "They don't have a huge network of blood vessels like that of humans, or tiny capillaries that you need a lot of pressure to flow blood through," Kunkel says. "They have an open circulatory system, which there's much less pressure in."

"After you cut their heads off, very often their necks would seal off just by clotting," he adds. "There's no uncontrolled bleeding."

The hardy vermin breathe through spiracles, or little holes in each body segment. Plus, the roach brain does not control this breathing and blood does not carry oxygen throughout the body. Rather, the spiracles pipe air directly to tissues through a set of tubes called tracheae.

Cockroaches are also poikilotherms, or cold-blooded, meaning they need much less food than humans do. "An insect can survive for weeks on a meal they had one day," Kunkel says. "As long as some predator doesn't eat them, they'll just stay quiet and sit around, unless they get infected by mold or bacteria or a virus. Then they're dead."

Entomologist Christopher Tipping at Delaware Valley College in Doylestown, Pa., has actually decapitated American cockroaches (*Periplaneta americana*) "very carefully under microscopes," he notes. "We sealed the wound with dental wax, to prevent them from drying out. A couple lasted for several weeks in a jar."

Insects have clumps of ganglia—nerve tissue agglomerations—distributed within each body segment capable of performing the basic nervous functions responsible for reflexes, "so without the brain, the body can still function in terms of very simple reactions," Tipping says. "They could stand, react to touch and move."

And it is not just the body that can survive decapitation; the lonely head can thrive, too, waving its antennae back and forth for several hours until it runs out of steam, Kunkel says. If given nutrients and

refrigerated, a roach head can last even longer.

Still, in roaches, "the body provides a huge amount of sensory information to the head and the brain cannot function normally when denied these inputs," explains neuroscientist Nick Strausfeld of the University of Arizona, who specializes in arthropod learning, memory and brain evolution. For instance, although cockroaches have a fantastic memory, "when we've tried to teach them when they had bits of them missing, it's hopeless. We have to keep their bodies completely intact."

Cockroach decapitation may seem macabre, but scientists have conducted many experiments with headless roach bodies and bodiless roach heads. Decapitating roaches deprives their bodies of hormones from glands in their heads that control maturation, helping researchers investigate metamorphosis and reproduction. And studies of bodiless roach heads shed light on how their neurons work. Plus, it provides just one more testament to the cockroach's enviable endurance.

--Originally published: Scientific American Online March 15, 2007.

UV Light Puts Spiders "in the Mood"

by John Matson

Ultraviolet (UV) light—the band of electromagnetic radiation nestled between visible light and x-rays—seems to cast a particularly amorous glow on the animal world. For instance, the budgie, an Australian parrot, is known to respond negatively to potential mates whose plumage has been stripped of its UV-induced fluorescence (wherein ultraviolet light is absorbed and light of a different, usually visible, wavelength is emitted). And although we humans cannot see UV light, as birds and many other animals can, we have incorporated lamps that produce it into some of our modern courtship rituals—just ask anyone who has ever hit the tanning beds in hopes of snaring a mate or any teen whose idea of setting the mood involves shining a black light on a Pink Floyd poster (which then, like the plumage of a budgie, fluoresces visible light).

The most illuminating example of the potential of ultraviolet romance, though, just might come from a jumping spider. As described in a January 26 paper in *Science*, researchers have shown that the *Cosmophasis umbratica* spider not only needs UV light (a constituent of sunlight) to instigate normal mating behavior, but that males and females of the species respond to it in physiologically distinct ways.

C. umbratica males feature scales on their face and body that reflect ultraviolet light, whereas the females do not. (Jumping spiders possess UV receptors in their retinas, so they can detect its emission or reflectance.) The females do, however, possess something the males lack: the ability to fluoresce bright green under UV illumination. Having recognized this distinction, the researchers decided to examine what role this gender-specific physiology plays in mating. So they blocked the ultraviolet wavelengths and observed what might be the arachnid equivalent of a cold shower. "It kind of ruined their sex life, really," says Michael Land, professor of neurobiology at the University of Sussex in England and one of the authors of the *Science* paper.

The sexual preferences of this species are easily observable, because an interested *C. umbratica* "has, like many jumping spiders, a fairly colorful mating dance," Land notes. "The males do this kind of Highland fling in front of the females." Females, for their part, have their own come-hither protocol: "They either stay still or they go for a little run and then come back again," he says. Under UV-blocked light, the authors report, "a large proportion of the same pairs that successfully interacted in the presence of UV failed to show intersexual behavior in its absence." Most males "failed to court the female when she lacked fluorescence," and most females similarly snubbed males not reflecting UV.

While the aforementioned budgies also disdain suitors in the absence of UV-induced cues, "it just seems to be rather like having a shirt at the disco under UV light, which glows if you wash it in the right washing powder," Land says. "But that's both sexes and just seems to be a property of the yellow pigments. So this is different. This is a sexual badge, if you like." Whether that badge acts as an aphrodisiac or merely a prerequisite identifier remains unclear. "I don't know how you distinguish between the two. Because if they identify [another spider] as the wrong species, this is obviously not going to be very aphrodisiacal," Land explains. The two roles, he adds, are "obviously going to go together, and it's almost impossible, I think, to disentangle them."

Even if the presence of UV had no effect on *C. umbratica* courtship, and even if the spiders were unified in their UV-induced signaling—that is, if both sexes reflected UV or both fluoresced green under UV—the species would still be in elite company: "Ultraviolet reflectance is not particularly common in animals," says Thomas Cronin, a vision researcher and professor of biological sciences at the University of Maryland, Baltimore County. And as for fluorescence, Cronin says, "it's not thought to be that common; we don't have very many examples of it." Still, he adds, "it would be easy to miss, because you kind of have to look for it rigorously."

Land says his colleagues have "big, big plans" to do just that—to look at other species and determine whether this type of signaling is unique to *C. umbratica* or more widespread. Whatever these further experiments reveal, this much is already clear: one species, for ultraviolet light at least, seems to have reached some sort of consensus on the age-old lights on–lights off debate.

--Originally published: Scientific American Online March 29, 2007.

Cats Cannot Taste Sweets

by David Biello

Sugar and spice and everything nice hold no interest for a cat. Our feline friends are only interested in one thing: meat (except for saving up the energy to catch it by napping, or a round of restorative petting) This is not just because inside every domestic tabby lurks a killer just waiting to catch a bird or torture a mouse, it is also because cats lack the ability to taste sweetness, unlike every other mammal examined to date.

The tongues of most mammals hold taste receptors—proteins on the cellular surface that bind to an incoming substance, activating the cell's internal workings that lead to a signal being sent to the brain. Humans enjoy five kinds of taste buds (possibly six): sour, bitter, salty, umami (or meatiness) and sweet (as well as possibly fat). The sweet receptor is actually made up of two coupled proteins generated by two separate genes: known as *Tas1r2* and *Tas1r3*.

When working properly, the two genes form the coupled protein and when something sweet enters the mouth the news is rushed to the brain, primarily because sweetness is a sign of rich carbohydrates —an important food source for plant-eaters and the nondiscriminating, like humans. But cats are from the noble lineage Carnivora and, unlike some of its lesser members, such as omnivorous bears or, even more appalling, herbivorous pandas, they exclusively eat meat.

Whether as a result of this dietary choice or the cause of it, all cats—lions, tigers and British longhairs, oh my—lack 247 base pairs of the amino acids that make up the DNA of the *Tas1r2* gene. As a result, it does not code for the proper protein, it does not merit the name gene (only pseudogene), and it does not permit cats to taste sweets. "They don't taste sweet the way we do," says Joe Brand, biochemist and associate director at the Monell Chemical Senses Center in Philadelphia. "They're lucky. Cats really have bad teeth as it is."

Brand and his colleague Xia Li first discovered the pseudogene after decades of anecdotal evidence, such as cats showing no preference between sweetened and regular water, unlike other animals—testifying to their indifference to the sweet stuff. Of course, there are also plenty of anecdotal accounts pointing in the other direction: cats that eat ice cream, relish cotton candy, chase marshmallows. "Maybe some cats can use their [*Tas1r3* receptor] to taste high concentrations of sugar," Brand says. "It's a very rare thing but we don't know yet."

Scientists do know, however, that cats can taste things we cannot, such as adenosine triphosphate (ATP), the compound that supplies the energy in every living cell. "There isn't a lot hanging around in meat, but it's a signal for meat," Brand says. And plenty of other animals have a different array of receptors, Li says, from chickens that also lack the sweet gene to catfish that can detect amino acids in water at nanomolar concentrations. "Their receptor is more sensitive than the background concentration," Brand notes. "The catfish that detects the rotting food first is the one that survives."

So far, cats are alone among mammals in lacking the sweet gene; even close relatives among the meat-eaters like hyenas and mongooses have it. And cats may lack other components of the ability to enjoy (and digest) sugars, such as glucokinase in their livers—a key enzyme that controls the

metabolism of carbohydrates and prevents glucose from flooding the animal. Despite this, most major pet food manufacturers use corn or other grains in their meals. "This may be why cats are getting diabetes," Brand offers. "Cat food today has around 20 percent carbohydrates. The cats are not used to that, they can't handle it." What these fearsome predators of suburbia cannot taste may be hurting them. But it also means that most cat lovers don't have to worry about Simon snatching their unattended dessert.

--Originally published: Scientific American Online August 16, 2007.

Elephants Never Forget

by James Ritchie

Elephants do not have the greatest eyesight in the animal kingdom, but they never forget a face. Carol Buckley at The Elephant Sanctuary in Hohenwald, Tenn., for instance, reports that in 1999 resident elephant Jenny became anxious and could hardly be contained when introduced to newcomer Shirley, an Asian elephant.

As the animals checked one another out with their trunks, Shirley, too, became animated and the two seemingly old friends had what appeared to be an emotional reunion. "There was this euphoria," sanctuary founder Buckley says. "Shirley started bellowing, and then Jenny did, too. Both trunks were checking out each other's scars. I've never experienced anything that intense without it being aggression."

Turns out the two elephants had briefly crossed paths years earlier. Buckley knew that Jenny had performed with the traveling Carson & Barnes Circus, before coming to the sanctuary in 1999, but she knew little about Shirley's background. She did a little digging, only to discover that Shirley had been in the circus with Jenny for a few months—23 years earlier.

Remarkable recall power, researchers believe, is a big part of how elephants survive. Matriarch elephants, in particular, hold a store of social knowledge that their families can scarcely do without, according to research conducted on elephants at Amboseli National Park in Kenya.

Researchers from the University of Sussex in England discovered that elephant groups with a 55-year-old matriarch (elephants live around 50 to 60 years) were more likely to huddle in a defensive posture than those with a matriarch aged 35 when confronted by an unfamiliar elephant. The reason: they were aware such strangers were likely to start conflicts with the group and possibly harm calves, Karen McComb, a psychologist and animal behaviorist at Sussex, and her colleagues reported in *Science*.

Other researchers, who studied three herds of elephants during a severe 1993 drought at Tanzania's Tarangire National Park, found that they not only recognize one another but also recall routes to alternate food and water sources when their usual areas dry up.

The scientists from the Wildlife Conservation Society (WCS) in New York City reported in *Biology Letters* that pachyderm groups with matriarchs, ages 38 and 45, left the parched park, apparently in search of water and grub, but the ones with a younger matriarch, age 33, stayed put.

Sixteen of 81 calves born in the park that year died in a nine-month period, a 20 percent mortality rate, much higher than the typical 2 percent; 10 of the dead were from the group that remained in the park, where feed and water were scarce.

Researchers concluded that the older elephants recalled a drought in the park that lasted from 1958 to 1961, and how their packs survived the slim pickings by migrating to lusher areas a distance away. None of the elephants that stayed behind were old enough to remember the previous dry spell.

Elephants also apparently recognize and can keep track of the locations of as many as 30 companions at a time, psychologist Richard Byrne of the University of Saint Andrews in Scotland and other researchers discovered during a 2007 study at Amboseli.

"Imagine taking your family to a crowded department store and the Christmas sales are on," Byrne says. "What a job to keep track of where four or five family members are. These elephants are doing it with 30 traveling-mates."

The scientists tested this memory by placing urine samples in front of female elephants, who thoroughly checked them with their trunks and acted up when they came across one that did not come from a member of their brood, and thereby should not have been there. "Most animals that hang around in packs, such as deer, probably have no idea who the other animals in their pack are," Byrne says. But elephants "almost certainly know every [member] in their group."

Such "working memory" is "far in advance of anything other animals have been shown to have," Byrne adds, and helps the elephant monitor the family units that move, forage and socialize together.

When it comes to smarts, elephants are right up there with dolphins, apes and humans, says WCS cognitive scientist Diana Reiss and colleagues at Emory University in Atlanta. They reported in 2006 in the *Proceedings of the National Academy of Sciences USA* that elephants, like the other mammals in that exclusive circle, are the only animals known to recognize their reflections in a mirror.

Zoologist Iain Douglas-Hamilton, founder of Save the Elephants in Nairobi, Kenya, is an authority on pachyderms who has studied them since the 1960s. He recounts becoming so well acquainted with an elephant in Tanzania's Lake Manyara National Park early in his career that he could actually walk beside her in the wild. He left the area in 1969 to write his thesis and did not return again for four years. But when he came back, he says, it was as though he'd never left. "She came right back up to me and behaved the same way," he says, noting that they resumed their friendly strolls.

"They're long-lived animals, and memory would be a benefit to a long-lived animal, making it more adaptive to circumstances," Douglas-Hamilton says. "Clearly if elephants experience extremes of climate and they can remember where the food is during a year, they can survive."

So the next time someone says you have a memory like an elephant, take it as a compliment.

--Originally published: Scientific American Online January 12, 2009.

Whale Waste Is Extremely Valuable

by Cynthia Graber

A ten-year-old vacationing in Wales stumbles across a lump worth nearly $6,000. A 67-year-old New York native receives a candlelike rock in the mail from her 80-year-old sister and discovers she may be $18,000 richer. All because a whale had a bit of indigestion. That upset stomach creates ambergris, a rare substance that has been highly valued for thousands of years as an ingredient in perfume and pharmaceuticals. Ambergris originates in the intestines of male sperm whales after they dine on squid, whose hard, pointy beaks abrade the whales' innards. Scientists believe that the whales protect themselves by secreting a fatty substance in their intestines to surround the beaks. Eventually the animals cast out a huge lump, up to hundreds of pounds at a time.

But don't refer to it as "whale vomit"; scientists postulate that whales do not expel ambergris through their mouths. No one has ever seen a sperm whale excrete ambergris, although sperm whale expert Hal Whitehead of Dalhousie University in Halifax, Nova Scotia, admits that it is assumed the voiding takes place as fecal excretion, because when first cast out, he says, "Well, it smells more like the back end than the front."

Viscous, black, stinky blocks of freshly expelled ambergris float on the ocean's surface. Sun, air and salt water oxidize the mass, and water continually evaporates. It hardens, breaks into smaller chunks and eventually becomes grey and waxy, embedded with small black squid beaks. The weathered chunks exude a sweet, earthy aroma likened to tobacco, pine or mulch. The quality—and value—of any given chunk depend on how much time it had spent floating or otherwise aging, says expert ambergris broker Bernard Perrin, because "it ages like fine wine."

For thousands of years this sea treasure has been highly prized. Middle Easterners historically powdered and ingested it to increase strength and virility, combat heart and brain ailments, or to spice food and drink. The Chinese called it "dragon's spittle fragrance." Ancient Egyptians burned it as incense. A British medical treatise from the Middle Ages informs readers that ambergris can banish headaches, colds and epilepsy, among other ailments. And the Portuguese took over the Maldives in the sixteenth century in part to gain access to the island's rich bounty of the redolent stuff.

The Arabic *anbar* refers to this very whale-based substance and is the root of the word amber. Centuries ago the French employed *amber gris* and *amber jaune* (gray amber and yellow amber) to distinguish between animal-based ambergris and what today has become the standard meaning: the golden-hued vegetal resin.

Like other animal-based perfume components (such as musk) ambergris has a scent all its own—derived from its chemical component ambrein—that it imparts to popular perfumes such as Chanel No. 5. It also enriches the other olfactory notes of a perfume, much as salt enhances flavors and spices, and, most importantly, it prolongs a perfume's other scents. As odor chemist George Preti of the Monell Chemical Senses Center in Philadelphia explains, ambergris molecules are lipophilic (fat-loving), as are perfume molecules, but the ambergris molecules are larger and heavier. "The odor molecules have a high affinity for the other lipophilic molecules, so they stay associated with the ambergris molecules and don't go into the vapor phase all at once," Preti says.

American perfume companies no longer mix ambergris into their fragrances, most likely because of confusing legalities surrounding its sale here. Internationally, however, the trade is legal and Perrin has no problem finding French perfume companies to buy his stock. "We also sell it to a royal family in the Middle East and they use it as an aphrodisiac. Apparently they take some milk, some honey, and grind up small quantities of the amber and put that in as well," he says.

Many aspects of ambergris remain a mystery. Why is ambergris more commonly found in the southern hemisphere, though sperm whales range all the world's seas? Why is it only sperm whales—and particularly male sperm whales—that create it? How did ancient Middle Easterners decide to start using it for medicine, or decide that "eau de whale" would be a compelling fragrance?

Some, but not all, scent qualities of ambergris have been synthesized, so the original remains valuable. With sperm whale numbers down from the 1.1 million estimated prior to whaling to approximately 350,000 today, less ambergris floats on the seas. Still, Whitehead says the population is slowly recovering, and even though most findings turn out to be rocks or wax or other ocean detritus, beachcombers and fishermen continue to scour the sands and waves in hope of stumbling across a weathered chunk of this sea gold.

--Originally published: Scientific American Online April 26, 2007.

For Baby Birds and other Critters, Human Touch Is Taboo

by Robynne Boyd

It's a familiar summer scenario: a nest rests in the low crook of a crab apple tree. Inside, a baby oriole stretches its wings, attempting to trill. A little girl's face looms overhead. She reaches out her colossal finger to stroke the still-wet feathers. Just before contact, her father's voice booms: "Don't touch that bird!"

According to folklore, birds will reject their eggs and young if humans have so much as laid a finger on them. This prevalent belief, however, is for the birds: it denies animal parents' innate drive to nurture their broods and ignores a bird's basic biology.

No matter how flighty birds appear, they do not readily abandon their young, especially not in response to human touch, says Frank B. Gill, former president of the American Ornithologists' Union. "If a bird's nest is disturbed by a potential predator during the nesting or egg-laying stage," he says, "there's a possibility that [it] will desert and re-nest. However, once the young are hatched and feeding, [their parents are] by and large pretty tenacious."

The myth derives from the belief that birds can detect human scent. Actually, birds have relatively small and simple olfactory nerves, which limit their sense of smell. There are very few birds with extraordinary olfaction and these represent specialized adaptations. For example, turkey vultures are attracted to methyl mercaptan, a gas produced by decaying organic matter (and added to natural gas to make it smell bad), while starlings can detect insecticidal compounds in vegetation, which they utilize to keep their nests bug-free. Yet no bird's sense of smell is cued to human scent.

Still, there's good reason not to go fiddling around in an occupied nest. "The fact is, birds don't abandon their young in response to touch, [but] they will abandon [their offspring and their nest] in response to disturbance," explains biologist Thomas E. Martin of the University of Montana and the U.S. Geological Survey, who has handled birds from Venezuela to Tasmania without instigating abandonment. "They are likely responding to disturbance in relation to risk of harm to young."

In other words, birds, like economists, make cost-benefit decisions. If a bird has invested a lot of time and energy in hatching and rearing its young, that bird is more likely to, if possible, relocate its offspring to a new nesting site, rather than abandon them altogether when a potential predator has discovered the babies. Birds that live longer, like hawks, are more averse to risk (and more sensitive to disturbance) than short-lived birds, like robins and other songbirds. The former might abandon its young, while the latter is much less likely to do so.

The same logic applies to most animals. "In general, wild animals bond with their young and do not quickly abandon them," explains Laura Simon, field director for the Urban Wildlife Program at the Humane Society of the United States.

In fact, most creatures find extraordinary ways to ensure the survival of their young. Killdeer and ducks will feign a broken wing to lure a predator away from their babies, and raccoons and tree squirrels will speedily relocate their progeny to more protected pastures when a potential threat is skulking about.

Wild rabbits are the exception to this rule. "These animals seem to be the most sensitive to human and other smells. They're a flighty, high-stress species," Simon says. "Wild rabbits will sometimes abandon their nest when it's been very disturbed as when a lawnmower [runs it over or a] cat gets into it."

If you suspect that a rabbit's nest has been abandoned, the Humane Society recommends making an "X" out of yarn or string over the nest and checking approximately 10 hours later to see if it has been moved. If the X has been pushed aside but the nest is still covered, that's a good indication that the mother has returned, nursed her young, and then re-covered them. If the X stays in place for 12 hours after the traumatic event, it's likely that the young rabbits have been deserted.

Of course, wild animals should be left undisturbed as much as possible. The general rule for finding a baby bird or any animal infant on the ground is simply to leave them alone. Most often, the parents are watching from a distance. But if a baby bird is found on the ground without its fledgling feathers and the nest is easily within reach, it can be returned without harm. The parents will welcome it back with open wings.

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Pets Protect Children against Allergies

by Melinda Wenner

Pets do an awful lot for kids: they teach them about unconditional love, responsibility, death and, of course, pooper scoopers. But does a dog or cat also keep a child from developing allergies? Despite decades of research, the short answer is still a frustrating "maybe."

The idea that pets might provide an immune benefit stems from a controversial theory born in 1989 called the hygiene hypothesis. It postulates that the sharp rise in allergic diseases this century can be explained, at least in part, by our higher cleanliness standards. Microorganisms like bacteria and parasites are thought to "prime" our immune systems to fight the important fights—dangerous infections—while smartly ignoring the frivolous ones. Allergies, then, occur because naive immune systems unnecessarily attack harmless environmental triggers, such as pet dander. Today, most researchers believe that only certain microorganisms, such as parasitic worms and lactobacilli, play a role in prepping the immune system. The question is whether pets provide some of them.

Studies designed to address this question, however, have been anything but conclusive. "Welcome to a complex field," says Thomas Platts-Mills, head of the allergy and clinical immunology division at the University of Virginia. For one thing, because cat and dog allergens like dander and saliva travel easily on clothing and in the air, most children are exposed to them—so it's not a black-and-white issue of exposure versus nonexposure. "The question is really, what happens at much higher exposure, that is, when there is a cat in the home?" says Matthew Perzanowski, an environmental health scientist at Columbia University's Mailman School of Public Health.

According to Perzanowski, pet ownership appears to be associated with a decreased risk of developing allergies in some, but not all, communities. For example, in countries with lots of cats, like the suburban U.S. and Australia, a pet cat appears to provide a protective effect. But in countries with few cats, he says, ownership actually increases the risk for allergic sensitization, the immune reaction that often precedes allergy symptoms. And don't even try to understand countries with moderate cat ownership—studies have been inconclusive. As for why these differences exist, no one really knows.

There's stronger evidence for protection from dogs, says Augusto Litonjua, an associate physician at Brigham's and Women's Hospital in Boston, but he admits that there could be a number of reasons for this. For instance, he says, how can you distinguish between the direct effect of owning a dog and the lifestyle choices that accompany it, such as going outside more, being more physically active, and absorbing more sun and vitamin D? It may not be the dog *per se* that's having an effect, he says.

But there is some molecular evidence for dog-specific protection. Dogs are known to carry lots of bacterial compounds called endotoxins in their fur, Litonjua says. His lab's studies have shown that when cells from children who have grown up in homes with higher endotoxin levels are directly exposed to allergens in the laboratory, they release fewer cytokines, chemicals associated with allergic responses.

Endotoxin exposure might also explain the well-supported finding that children raised on farms

experience fewer allergy symptoms than other kids. Farms are chock-full of microorganisms and animals, and these might confer a protective effect; but again, farm children lead very different lives than kids raised elsewhere, so it's difficult to tease out exactly what is protecting them, Litonjua says.

Indeed, some scientists urge caution when it comes to interpreting the majority of pet allergy studies out there. In many, researchers questioned groups of people about their pet ownership patterns and compared this with their allergy profiles.

Such studies don't prove causation, says Carl-Gustaf Bornehag, a public health scientist at Karlstad University in Sweden. Often, people who are allergic to pets—or, because allergies are at least partially hereditary, people who are at risk of becoming allergic because someone in their family is—simply aren't going to own them, he says.

This skews study results, making it appear that pets protect against allergies when they actually don't. Although some studies have tried to circumvent this potential bias by stratifying results based on hereditary risk, "until there is a 'randomized distribution of cats trial,'" says Columbia's Perzanowski, "there will always be some chance of confounding by who chooses to own a cat,"—or a dog, for that matter.

So should parents get a pet if they want to minimize their child's risk of developing allergies? "That's the million dollar question," says Litonjua, and the short answer, he says, is no. "If you want to get to get a pet to try and prevent allergies, that's probably not a good reason," he explains. But "if the kids really want the pet—if you want the pet—then go ahead, as long as you're not having any symptoms when you get exposed." Flea bites and poop aversion, of course, don't count.

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Mushroom Outsizes Blue Whale as World's Largest Organism

by Anne Casselman

Next time you purchase white button mushrooms at the grocery store, just remember, they may be cute and bite-size but they have a relative out west that occupies some 2,384 acres (965 hectares) of soil in Oregon's Blue Mountains. Put another way, this humongous fungus would encompass 1,665 football fields, or nearly four square miles (10 square kilometers) of turf.

The discovery of this giant *Armillaria ostoyae* in 1998 heralded a new record holder for the title of the world's largest known organism, believed by most to be the 110-foot- (33.5-meter-) long, 200-ton blue whale. Based on its current growth rate, the fungus is estimated to be 2,400 years old but could be as ancient as 8,650 years, which would earn it a place among the oldest living organisms as well.

A team of forestry scientists discovered the giant after setting out to map the population of this pathogenic fungus in eastern Oregon. The team paired fungal samples in petri dishes to see if they fused, a sign that they were from the same genetic individual, and used DNA fingerprinting to determine where one individual fungus ended.

This one, *A. ostoyae*, causes Armillaria root disease, which kills swaths of conifers in many parts of the U.S. and Canada. The fungus primarily grows along tree roots via hyphae, fine filaments that mat together and excrete digestive enzymes. But *Armillaria* has the unique ability to extend rhizomorphs, flat shoestringlike structures, that bridge gaps between food sources and expand the fungus's sweeping perimeter ever more.

A combination of good genes and a stable environment has allowed this particularly ginormous fungus to continue its creeping existence over the past millennia. "These are very strange organisms to our anthropocentric way of thinking," says biochemist Myron Smith of Carleton University in Ottawa, Ontario. An *Armillaria* individual consists of a network of hyphae, he explains. "Collectively, this network is called the mycelium and is of an indefinite shape and size."

All fungi in the *Armillaria* genus are known as honey mushrooms, for the yellow-capped and sweet fruiting bodies they produce. Some varieties share this penchant for monstrosity but are more benign in nature. In fact the very first massive fungus discovered in 1992—a 37-acre (15-hectare) *Armillaria bulbosa*, which was later renamed *Armillaria gallica*—is annually celebrated at a "fungus fest" in the nearby town of Crystal Falls, Mich.

Myron Smith was a PhD candidate in botany at the University of Toronto when he and colleagues discovered this exclusive fungus in the hardwood forests near Crystal Falls. "This was kind of a side project," Smith recalls. "We were looking at the boundaries of [fungal] individuals using genetic tests and the first year we didn't find the edge."

Next, the microbiologists developed a new way to tell an individual apart from a group of closely related siblings using a battery of molecular genetic techniques. The major test compared fungal genes for telltale signs of inbreeding, where heterozygous strips of DNA become homozygous. That's when

they realized they had struck it big. The individual *Armillaria bulbosa* they found weighed over 100 tons (90.7 metric tons) and was roughly 1,500 years old.

"People had ideas that maybe they were big but nobody had any idea they were that big," says Tom Volk, a biology professor at the University of Wisconsin–La Crosse. "Well it's certainly the biggest publicity that mycology is going to get—maybe ever."

Soon afterward, the discovery of an even bigger fungus in southwestern Washington was announced by Terry Shaw, then in Colorado with the U.S. Forest Service (USFS), and Ken Russell, a forest pathologist at Washington State Department of Natural Resources, in 1992. Their fungus, a specimen of *Armillaria ostoyae*, covered about 1,500 acres (600 hectares) or 2.5 square miles (6.5 square kilometers). And in 2003 Catherine Parks of the USFS in Oregon and her colleagues published their discovery of the current behemoth 2,384-acre *Armillaria ostoyae*.

Ironically, the discovery of such huge fungi specimens rekindled the debate of what constitutes an individual organism. "It's one set of genetically identical cells that are in communication with one another that have a sort of common purpose or at least can coordinate themselves to do something," Volk explains.

Both the giant blue whale and the humongous fungus fit comfortably within this definition. So does the 6,615-ton (six-million-kilogram) colony of a male quaking aspen tree and his clones that covers 107 acres (43 hectares) of a Utah mountainside.

And, at second glance, even those button mushrooms aren't so tiny. A large mushroom farm can produce as much as one million pounds (454 metric tons) of them in a year. "The mushrooms that people grow in the mushroom houses—they're nearly genetically identical from one grower to another," Smith says. "So in a large mushroom-growing facility that would be a genetic individual—and it's massive!"

In fact, humongous may be in the nature of things for a fungus. "We think that these things are not very rare," Volk says. "We think that they're in fact normal."

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Dogs Can Talk

by Tina Adler

Maya, a noisy, seven-year-old pooch, looks straight at me. And with just a little prompting from her owner says, "I love you." Actually, she says "Ahh rooo uuu!"

Maya is working hard to produce what sounds like real speech. "She makes these sounds that really, really sound like words to everyone who hears her, but I think you have to believe," says her owner, Judy Brookes.

You've probably seen this sort of scene on *YouTube* and David Letterman. These dog owners may be onto something: Psychologist and dog expert Stanley Coren of the University of British Columbia tells the story of a colleague who always greeted her dog, Brandy, with a cheerful, two-syllable "Hel-lo!" It wasn't long until Brandy returned the greeting, which sounded very much like her owner's salutation, says Coren, author of *How to Speak Dog: Mastering the Art of Dog–Human Communication.*

But do dogs really talk? Back in 1912 Harry Miles Johnson of Johns Hopkins University said, emphatically, "no." In a paper in *Science*, he generally agreed with the findings of Oskar Pfungst of the Institute of Psychology at the University of Berlin who studied a dog famous for its large vocabulary. The dog's speech is "the production of vocal sounds which produce illusion in the hearer," Johnson wrote.

He went on to warn that we should not be surprised if "scientists of a certain class…proclaim that they have completely demonstrated the presence in lower animals of 'intelligent imitation'."

Nothing in the last century has really changed that scientific opinion. (No one has ever questioned whether dogs communicate with each other, but calling it "talking" is something else.) So what are Maya and her cousins doing? It's more appropriate to call it imitating than talking, says Gary Lucas, a visiting scholar in psychology at Indiana University Bloomington. Dogs vocalize with each other to convey emotions—and they express their emotions by varying their tones, he says. So it pays for dogs to be sensitive to different tones. Dogs are able to imitate humans as well as they do because they pick up on the differences in our tonal patterns.

Lucas likens this behavior to that of bonobos, primates that can imitate some tonal patterns, including vowel sounds, pitch changes, and rhythms, studies show. "The vocal skills of some of the dogs and cats on *YouTube* suggest that they might also have some selective tonal imitation skills," he says.

What's happening between dog and owner-turned-voice-coach is fairly straightforward, Coren says: Owner hears the dog making a sound that resembles a phrase, says the phrase back to the dog, who then repeats the sound and is rewarded with a treat. Eventually the dog learns a modified version of her original sound. As Lucas puts it, "dogs have limited vocal imitation skills, so these sounds usually need to be shaped by selective attention and social reward."

In the Letterman video "a pug says, 'I love you' and it's very cute, but the pug has *no* idea what it

means," Coren says. "If dogs could talk, they would tell you, 'I'm just in it for the cookies.'"

Scientists have made some progress in their study of this important subject: They've learned why dogs, and other animals, have rather poor pronunciation and, for example, completely botch consonants. They "don't use their tongues and lips very well, and that makes it difficult for them to match many of the sounds that their human partners make," Lucas says. "Try saying 'puppy' without using your lips and tongue."

Despite what they may lack in the elocution department, dogs *do* communicate their feelings to humans as well as read our cues, thanks to domestication, Julia Riedel and colleagues of the Max Planck Institute (M.P.I.) for Evolutionary Anthropology reported in March 2008 in *Animal Behavior*. Dogs follow people's pointing, body posture, the direction of their gaze, and touches for cues to find hidden food, notes Mariana Bentosela and colleagues at the University of Buenos Aires in the July 2008 *Behavioural Processes*. They also gaze at their trainer when they need more information to find their reward.

Some dogs learn to understand an impressive number of words, as well. A gifted border collie, Rico, mastered the names of more than 200 objects using a technique called fast-tracking that small children also employ, Juliane Kaminski, also of M.P.I. Evolutionary Anthropology and colleagues reported in 2004 in *Science*. The researchers introduced a novel item into Rico's mix of toys then asked him to retrieve it. He did so by associating the unfamiliar name with the unfamiliar object. He even remembered the name of the toy a month later.

"That's the kind of fast-tracking or exclusionary learning, which we used to think only human beings and the talking apes—the ones taught language—could use," Coren says. "For the psychologists it was, 'Wow, how did he learn that word?!'"

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Squid Can Fly

by Ferris Jabr

Marine biologist Silvia Maciá was boating on the north coast of Jamaica in the summer of 2001 when she noticed something soar out of the sea. At first she thought it was a member of the flying fish family—a group of marine fish that escape predators by breaking the water's surface at great speed and gliding through the air on unusually large pectoral fins. But after tracing the creature's graceful arc for a few seconds, Maciá realized this was no fish. It was a squid—and it was flying.

With her husband and fellow biologist Michael Robinson, Maciá identified the airborne cephalopod as a Caribbean reef squid (*Sepioteuthis sepioidea*)—a lithe, torpedo-shaped critter with long, undulating fins. They think the squid was startled by the noise of the boat's outboard engine and estimated that the 20- centimeter-long mollusk reached a height of two meters above the water and flew a total distance of 10 meters—50 times its body length. What's more, the squid extended its fins and flared its tentacles in a radial pattern while airborne, as though guiding its flight.

"It was doing this weird thing with its arms where it had them spread out almost in a circle," recalls Maciá, who teaches at Barry University in Florida. "It had its fins kind of flared out as much as it could—it really looked liked it was flying. It hadn't accidentally flopped out of the water; it was maintaining its posture in a certain way. It was doing something active."

Squid surveillance

On a LISTSERV dedicated to mollusks, Maciá and Robinson (University of Miami), called out for any other researchers who had witnessed airborne squid—a phenomenon the husband and wife had not personally observed before. Maciá and Robinson received numerous replies from scientists with whom they eventually co-wrote a study in 2004 in the *Journal of Molluscan Studies*. The paper collects sightings of at least six distinct squid species squirting themselves out of the ocean and over the waves, sometimes solo, sometimes in packs—sometimes with enough force to match the speed of boats or wind up on decks. But the paper includes no photographs or video clips; its evidence is largely anecdotal. The fact is that documented instances of flying squid are incredibly rare. Most people are unprepared for such a sight.

However, on a cruise ship off the coast of Brazil, retired geologist and amateur photographer Bob Hulse captured what may be the best-ever photographic evidence of flying squid. Hulse sent the pictures to University of Hawaii oceanographer Richard Young, who passed them along to Ron O'Dor, senior scientist for the Census of Marine Life. O'Dor thinks he can analyze the photos to gain a better understanding of squid aerodynamics, which few people have been able to properly study due to lack of adequate documentation.

"Hulse was shooting with burst mode on his camera, so I know exactly what the interval is between the frames and I can calculate velocity of squid flying though the air," O'Dor says. "We now think there are dozens of species that do it. Squid are used to gliding in the water, so the same physiology probably allows them to maneuver and glide in the air. When you look at some of the pictures, it seems they are more or less using their fins as wings, and they are curling their arms in [a] shape that

could easily be some kind of lifting surface."

From fin to wing

The 2004 paper's authors argue that "gliding" is too passive a term to describe what squid do when they leave the ocean for the air: "flight" is more fitting.

"From our observations it seemed like squid engage in behaviors to prolong their flight," Maciá says. "One of our co-authors saw them actually flapping their fins. Some people have seen them jetting water while in flight. We felt that 'flight' is more appropriate because it implies something active."

The aerodynamic benefit an airborne squid derives from flapping fins and spiraled tentacles is not clear, but some researchers hypothesize that these behaviors provide extra lift and help stabilize the squid when out of its primary element. In the water some squid spread their tentacles into a weblike pattern that facilitates swimming backward—a trick they could try to mimic in the air to gain an extra set of wings, some scientists have proposed. And rapidly changing the position of the tentacles could even function as a kind of brake.

Some squid don't rely on such subtle aerial acrobatics. Instead, like the squid photographed by Hulse, they forcibly propel themselves through the air. Some 370 kilometers off the coast of Sydney, Australia, one of the 2004 paper's co-authors witnessed a skipjack tuna chasing hundreds of what were probably arrow squid (*Nototodarus gouldi*). The school repeatedly leapt out of the ocean, spurting jets of water behind them as they flew through the air. Some arrow squid reached a height of three meters and flew a total distance of eight to 10 meters.

Fight or flight

For all these flying squid species, jet propulsion is the key for getting out of the water in the first place. First, a squid expands its mantle—the cloak of soft muscular tissue that surrounds its body—which fills with water. Then the squid quickly contracts it to send the trapped water shooting through a flexible tube below its head, called the funnel or siphon. By changing the position of this funnel, a squid can propel itself in almost any direction. Underwater, squid use jet propulsion to pounce on swift prey and escape intimidating predators. But sometimes jetting through the currents is not enough to make a successful getaway—sometimes, a squid needs to get out of the water altogether. So they fly.

Biologists still do not fully understand the mechanics of squid aeronautics, but based on accumulating anecdotal and photographic evidence, they have no doubt that the phenomenon is real and widespread. "Flying is not at all unusual in several families of squid," says Michael Vecchione, a squid expert at the Smithsonian Institution. In particular, the families Ommastrephidae and Onychoteuthidae are known for their loftiness. "It's not uncommon to find squid on the deck of the ship in the morning," Vecchione adds. Many squid remain in the dark depths during the day to avoid predators, Vecchione explains, but when they venture into shallower waters at night to feed they are liable to jump out of the water in a panic and onto a boat.

These morning-after encounters are not infrequent, but catching a squid in the act of flight is still quite a feat. "It just happens so fast," Maciá says. "You really have to be in the right place in the right

time."

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SECTION 2

Babies and Parents

Babies Resemble Their Fathers More Than Their Mothers

by John Matson

Does junior really have his father's nose?

A common bit of parenting folklore holds that babies tend to look more like their fathers than their mothers, a claim with a reasonable evolutionary explanation. Fathers, after all, do not share a mother's certainty that a baby is theirs, and are more likely to invest whatever resources they have in their own offspring. Human evolution, then, could have favored children that resemble their fathers, at least early on, as a way of confirming paternity.

The paternal-resemblance hypothesis got some scientific backing in 1995, when a study in *Nature* by Nicholas Christenfeld and Emily Hill of the University of California, San Diego, showed that people were much better at matching photos of one-year-old children with pictures of their fathers than with photos of their mothers. (*Scientific American* is part of Nature Publishing Group.)

Case closed? Hardly. "It's a very sexy result, it's seductive, it's what evolutionary psychology would predict—and I think it's wrong," says psychologist Robert French of the National Center for Scientific Research in France. A subsequent body of research, building over the years in the journal *Evolution & Human Behavior*, has delivered results in conflict with the 1995 paper, indicating that young children resemble both parents equally. Some studies have even found that newborns tend to resemble their mothers more than their fathers.

In a 1999 study published in *Evolution & Human Behavior*, French and Serge Brédart of the University of Liège in Belgium set out to replicate the paternal-resemblance finding and were unable to do so. In a photo-matching trial with pictures of one-, three- and five-year-old children and their parents, subjects identified mothers and fathers equally well.

A more recent study in the same journal employed a larger set of photos than were used by either Christenfeld and Hill or Brédart and French in their studies and still concluded that most infants resemble both parents equally. "Our research, on a much larger sample of babies than Christenfeld and Hill's, shows that some babies resemble their father more, some babies resemble their mother more, and most babies resemble both parents to about the same extent," says Paola Bressan, a psychologist at the University of Padova in Italy who co-authored the 2004 study. Bressan added that, to the best of her knowledge, "no study has either replicated or supported" the 1995 finding that babies preferentially resemble their fathers.

Two other studies in *Evolution & Human Behavior*, one in 2000 and one in 2007, found that newborns actually look more like their mothers than their fathers in the first three days of their lives, as judged by unrelated assessors. But the babies' mothers tend to say just the opposite, emphasizing the child's resemblance to the father. That, too, has a possible evolutionary explanation, according to D. Kelly McLain of Georgia Southern University and his co-authors of the 2000 study. "The bias in how mothers remark resemblance does not reflect actual resemblance and may be an evolved or conditioned response to assure domestic fathers of their paternity," the researchers wrote.

McLain and his colleagues even speculated that evolutionary pressures may have actually reduced

the amount of paternal resemblance in newborns, thus ensuring that a putative father will care for a child even if the father has been cuckolded. That both high and low degrees of paternal resemblance have ready explanations highlights one of the challenges in linking subtle human features to changes that played out over millions of years of evolution. "It's kind of hard to distinguish 'just-so' stories from things that are really a product of evolution," French says.

--Originally published: Scientific American Online June 18, 2011.

Artificial Reproduction Leads to Sickly Children

by Katie Cottingham

Most children conceived via assisted reproductive technology (ART), such as superovulation are fine, although some recent studies are raising doubts about whether these fertility fixes are as safe as promised. The extensive handling of these crucial cells is a concern, and there are mixed reports on the long-term health of these hard-won children, with several studies suggesting increased risks of low birth weight, rare disorders down the line, and even death.

For starters, one study published in July 2009 links ART embryos with poor health outcomes along a few dimensions. Another paper, from January 2010, shows that the genes in ART embryos bear different epigenetic marks than non-ART embryos. And the laboratory procedure of ART itself, during which eggs, sperm and embryos are typically sucked in and out of pipettes and left to sit in culture dishes, concerns some researchers and potential parents alike. Scientists such as Mellissa Mann, a researcher at Children's Health Research Institute in Canada and the University of Western Ontario, speculate that these manipulations could affect the health of ART babies.

"More attention should be paid to the safety of ART offspring as they now account for the large proportion of the population," says He-Feng Huang, an obstetrician and gynecologist at Affiliated Women's Hospital and Zhejiang University School of Medicine in China. Indeed, according to a 2009 study published in *Human Reproduction*, the number of ART procedures is on the rise and so-called testtube babies account for an estimated 250,000 births every year worldwide.

ART encompasses several techniques: With superovulation, women receive high doses of hormones to stimulate egg production. Eggs and sperm are brought together in a dish so that in vitro fertilization (IVF) will take place. If a man's fertility is low a single sperm cell can be chosen and injected into an egg, forcing fertilization. Another procedure, called pre-implantation genetic diagnosis (PGD), involves removing one or two cells from an early-stage IVF embryo for genetic testing to screen for various diseases.

Molecular changes

The 2009 health outcomes work, by biologists Ran Huo, Qi Zhou and colleagues at the Chinese Academy of Sciences and Nanjing Medical University, involved comparing mice that had undergone IVF and PGD with those that had undergone IVF alone. The team reported in *Molecular and Cellular Proteomics* that, compared with controls, PGD mice were more forgetful, heavier and had less myelin (a fatty coating on nerves that allows electrical signals to move quickly across nerve cells). They also expressed abnormal levels of proteins involved in neurodegenerative conditions.

Although mouse outcomes do not always parallel those in humans, the lab animal studies are helpful because "when we're studying humans, we can't separate out the effect of the procedure versus fertility issues," Mann says. For example, it is hard to say whether an ART baby has died because of the ART technology or because one of its parents had a mutation that mutually contributed to subpar fertility and infant death.

Mann's group, for the 2010 work on ART and epigenetics, used mice to examine changes on four genes following a superovulation procedure. The team looked at methylation, in which a methyl group is placed onto cytosine in DNA sequences. Methylation typically silences genes so that they are not expressed. Mann's team reported in *Human Molecular Genetics* that superovulation affected the establishment and possibly the maintenance of methylation in mice. Messed-up methylation early in development can cause disorders, such as Beckwith-Wiedemann syndrome (an overgrowth disorder), in humans. Another study by a different group in the same journal in October 2009 looked at ART effects on epigenetics (non-DNA changes in genes) in humans. They found methylation defects on several human genes in the cord blood and placentas of ART embryos, suggesting that a similar effect might be occurring in humans as well.

Cause and effect

Molecular studies paint a potentially bleak picture, but researchers warn that the effects and causes of these differences are unknown. "I think it's hard to make any firm conclusions so far," says Liv Bente Romundstad, a fertility doctor and researcher at Saint Olav's University Hospital in Norway.

To tease out the effects of ART from the impact of underlying fertility issues in humans, Romundstad's team studied mothers who had one pregnancy with ART and one naturally. Because the women had children on their own either before or after ART, the researchers assumed that fertility was not a problem. Multiple births were excluded because even naturally conceived multiples have a high risk of complications, Romundstad says.

When ART babies were compared with the entire population they had a lower birth weight and increased risk of death around the time of birth, but that risk disappeared when compared with their siblings. The analysis, published in August 2008 in *The Lancet*, suggests, "the infertility treatment per se for the outcomes we have studied does not seem to give any additional risk," Romundstad says.

But there's still reason for concern. In a talk at the European Society of Human Genetics conference, Géraldine Viot, a clinical geneticist at the Maternity Hospital, Port Royal in Paris described her team's large study of French ART centers. Although ART children had a slightly higher than normal rate of birth defects, their risk of developing epigenetic disorders, such as Beckwith-Wiedemann syndrome, was 4.5 to six times higher.

So, is ART safe? "For some of these children, we still don't know what the long-term results of the ART will be, in that a lot of these children are not yet reproductive age," Mann points out. Romundstad says that although it's possible that health effects could surface later on, she will continue to offer fertility treatment in her practice. "I don't think the timing is right to start to scare the population, but I think it's important to focus on this and continue with studies," she says.

--Originally published: Scientific American Online July 1, 2010.

Fathers Can Get Postpartum Depression

by Katherine Harmon

Strange tales of lactating men or male pregnancy pains crop up in the news from time to time, despite the fact that men cannot get pregnant. Does that mean men are also susceptible to bouts with prenatal and postpartum depression?

Previous research has found rates of depression in new dads that range from 1 percent to 25 percent, but a meta-analysis, published in *JAMA, Journal of the American Medical Association*, assessed 43 studies of a total of more than 28,000 fathers and found that an average of 10.4 percent suffered from depression sometime between the first trimester of their partner's pregnancy and the child's first birthday.

Rates of paternal depression were highest three to six months after birth (25.6 percent) and in the U.S. (14.1 percent versus the international rate of 8.2 percent). All of these numbers are considerably higher than the annual rate for adult male depression, which is 4.8 percent (but lower than the rate for maternal prenatal and postpartum depression, which is estimated to be 23.8 percent).

"This suggests that paternal prenatal and postpartum depression represents a significant public health concern," concluded the authors of the new paper.

Many moms get what is known as the baby blues, a passing sadness in the first few days after the birth of their child. But postpartum depression in both mothers and fathers is a condition that lasts longer, and "it may be very problematic for families and child outcomes," says James Paulson of the Department of Pediatrics at Eastern Virginia Medical School, the lead author of the meta-analysis. Extreme examples of parental depression can lead to suicide or to harm or neglect of the baby, but even mild to moderate depression in fathers has been shown to have lasting negative effects on their children for years to come.

Difficult diagnosis

Postpartum depression in moms has become a more widely discussed—and diagnosed—issue in recent years, but finding fathers who are going through something similar has proven difficult. Diagnostic questionnaires often focus on questions about sadness and other states that men typically are less likely to acknowledge. Some researchers have advocated to change the vocabulary to include issues such as irritability, emotional withdrawal and detachment, which can also be symptoms of depression in men, Paulson says.

Additionally, "there's a general cultural myth that men don't get depressed," says Will Courtenay, a psychotherapist and researcher in Oakland, Calif. who is completing research on paternal postpartum depression in collaboration with Harvard's Center for Men at McLean Hospital. "Because of that cultural myth, men oftentimes think they shouldn't get depressed, and when they are depressed they try to hide it."

Many new parents endure a host of symptoms often associated with depression (such as fatigue, change in appetite or anxiety), even if they have a clean bill of mental health. As a parent of an infant,

"you don't have time to eat a normal diet, you don't have time to get eight hours of sleep," Paulson notes. So "trying to parse out fatigue" and other normal indicators of depression can be tricky, he says. But for people who have clear cases of clinical depression, there are cues beyond typical parenting troubles, such as persistent detachment, feeling hopeless or worthless, or thoughts of death.

Finally, doctors and pediatricians usually see new fathers less often than they do new mothers, who are most frequently the parent bringing a baby in for appointments during the first year of life. Even though screening for depression in mothers is far from perfect, it is much easier to do given their more regular contact with the health care system, Paulson noted at a 2010 press briefing hosted by *JAMA* in New York.

Paternal biology

As the childbearers, women have been the primary focus for studies of physiological and psychological changes during and after pregnancy. But more recent literature has begun to uncover changes in dads as well. A few studies have found hormonal changes in men about to become fathers and those who have just had a child, Paulson notes, though he is quick to add that none have yet linked these changes specifically to depression. Many of these shifts, however, mirror those occurring during the same period in women's bodies, such as increases in estrogen and prolactin, Courtenay says.

The sleep deprivation that comes along with being a new parent can alter neurochemical balances in the brain, making some people with underlying risk factors more vulnerable to depression. "It's kind of a double whammy," Courtenay says. "All these hormonal changes and neurochemical changes in the brain due to sleep deprivation can wreak havoc on a man."

In part due to the paucity of research on paternal prenatal and postpartum depression, experts are still sketchy on the risk factors for fathers. A personal history of depression puts both mothers and fathers at a higher risk, as does a sick baby, financial strain or relationship problems. Add to that list the changing expectations pushing dads to become more involved parents, says Courtenay, and many new fathers are left feeling overwhelmed and at greater risk for anxiety and depressive symptoms.

Downsides of depressed dads

Like mothers who are depressed, fathers who suffer from depression can have negative impacts on their children's development years down the road.

"When Dad is depressed, Dad tends to interact less with the child and bonds less with the child," Paulson notes. He coauthored a study that found fathers with depression were less likely to read to their children, and those children were more likely to have relatively poor language skills.

A study of more than 10,000 children in the U.K., published in 2005 in *The Lancet*, found that "depression in fathers during the postnatal period was associated with adverse emotional and behavioral outcomes in children aged 3.5 years." This correlation was seen even when the researchers controlled for maternal depression, the authors, led by Paul Ramchandani of the University of Oxford, concluded.

Another study, published in 2008 in *The Journal of Child Psychology and Psychiatry*, found that

children whose fathers had been depressed during their early infancy were more likely to have behavioral problems by the time they were school age—a finding Paulson calls "very alarming." The longitudinal study, also led by Ramchandani, found that kids whose fathers had been depressed in both the prenatal stage and the first month of infancy "had the highest risk of subsequent psychopathology." And the effect was especially strong in boys who had had depressed fathers.

Depression in dads also seems to correlate with depression in mothers. Although the relationship is not one-to-one, having a partner with this sort of depression seems to increase an individual's likelihood of having it, too. This should prompt clinicians to assess the partners of parents with depression, Paulson says. Currently, however, he notes, "we don't know what direction that influence moves."

Addressing dads' depression

Although he has been studying paternal postpartum depression for several years, Paulson was surprised to find a big difference between rates in the U.S. and those from studies based elsewhere. U.S. fathers had nearly twice the rate of paternal prenatal and postpartum depression, leading Paulson and his coauthor, Sharnail Bazemore, also of Eastern Virginia Medical School, to suggest further research on the "varying social norms and postpartum work practices cross-nationally."

As in mothers, postpartum depression in fathers seems to spike between three and six months after the birth of a child. Paulson speculates that this might have to do with the typical three-month term for maternity leave in the U.S., after which many mothers return to work, shifting responsibilities within the family. It is also an age at which children start exhibiting more challenging behavior, he notes.

Paulson recommends investigating treatment that focuses on whole families, addressing depression "as a family problem, not an individual problem."

Courtenay proposes ways to help prevent paternal—and maternal—depression from becoming a problem in the first place. With a growing checklist of risk factors, he says, the best thing to do is address any of them "before the baby comes along." If there is a history of depression, be prepared for a relapse and have plans in place for seeking treatment quickly. If there is strife in the relationship between the parents, seek counseling or other help before or during pregnancy. Or if a father-to-be is starting to feel anxious about his new role and responsibilities, he should enroll in a parenting class. "Putting that stuff in order beforehand" can help keep disruptive parental depression at bay, Courtenay notes.

The first step, researchers seem to agree, is improving awareness that paternal prenatal and postpartum depression exists and is likely to affect about one in 10 fathers. With more than 10,000 children being born each day in the U.S. and more than 14 percent of U.S. fathers experiencing some depression during pregnancy or the first year of infancy, "that's not an insignificant number" of men who will get depressed, Courtenay says.

But experts are making headway in informing the medical community—and the general public. Paulson notes that most of the studies he found on paternal depression have been published in the past several years, and other indicators are looking up, as well. Not too long ago, typing "paternal depression" into Google would return the suggestion: "did you mean *maternal* depression," he noted

at the press conference today. The same search now quickly turns up more than 18,000 results.

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Males Can Lactate

by Nikhil Swaminathan

In late 2004 the Internet Movie Database reported that Dustin Hoffman suddenly had the urge to breast-feed. Had the then-67-year-old Hoffman—who brought mainstream culture face to face with autism in *Rain Man* and went mano a mano with an Ebola-like filovirus in *Outbreak*—never quite broken character from his 1982 film *Tootsie*? Nope. He was just really keen to help out with his first grandchild.

Interestingly, he could have possibly lent a helping, er, breast, if he had held the suckling newborn to his nipples for a couple weeks, although he could also have tried starving himself or taking a medication that would affect his brain's pituitary gland.

There have been countless literary descriptions of men miraculously breast-feeding, from *The Talmud* to Tolstoy, where, in *Anna Karenina*, there is a short anecdote of a baby suckling an Englishman for sustenance while on board a ship. The little anthropological evidence documented suggests it is possible. In the 1896 compendium *Anomalies and Curiosities of Medicine*, George Gould and Walter Pyle catalogue several instances of male nursing being observed. Among them was a South American man, observed by Prussian naturalist Alexander von Humboldt, who subbed as wet nurse after his wife fell ill as well as male missionaries in Brazil that were the sole milk supply for their children because their wives had shriveled breasts. More recently, Agence France-Presse reported a short piece in 2002 on a 38-year-old man in Sri Lanka who nursed his two daughters through their infancy after his wife died during the birth of her second child.

In her 1978 book *The Tender Gift: Breastfeeding*, medical anthropologist Dana Raphael claimed that men could induce lactation simply by stimulating their nipples. The eminent endocrinologist Robert Greenblatt of the Medical College of Georgia concurred. But Jack Newman, a Toronto-based doctor and breast-feeding expert, insists that in order to produce milk, a hormone spike must occur. "That Tolstoy quote suggests that the father just put the baby to the breast and he would produce milk; I think that's pretty unlikely," he says. "It could be that you have this man with this pituitary tumor and he produces milk once the baby starts suckling."

Newman explains that medical disruptions involving prolactin, the hormone necessary to produce milk, have resulted in spontaneous lactation. Thorazine, a popular antipsychotic used in the mid-20th century, impacted the pituitary gland—the pea-size endocrine gland located near the base of the brain—often causing it to overproduce prolactin. If prolactin levels remained high, milk could follow. According to Newman, lactation is listed as a possible side effect of the heart medication digoxin. A pituitary tumor could also induce milk production: "It would be the same reason—increased prolactin levels—in the one case drug-induced, in the other due to a tumor or some other sort of neurological problem."

In a 1995 article for *Discover* titled "Father's Milk," Pulitzer Prize-winning author and one-time physiologist Jared Diamond reconciles the nipple stimulation and hormone quandary, pointing out that such stimulation can release prolactin. He also notes that starvation—which inhibits the functioning of hormone-producing glands as well as the hormone-absorbing liver—can cause spontaneous lactation,

as observed in survivors of Nazi concentration camps and Japanese POW camps in World War II. "The glands recover much faster than the liver when normal nutrition is resumed," he writes, "so hormone levels soar unchecked."

Males of many different mammalian species have the potential to lactate, although only one, the Dayak fruit bat of Southeast Asia, does so spontaneously. Diamond points out, however, that with the societal norm of fathers helping to rear their young, male milk production could actually be to our advantage, especially with all the career women trying to balance the demands of job and family. Why else would men still have nipples?

"Up until a certain age, boys and girls, as fetuses, are indistinguishable, really, so women retain some remnants of the vas deferens, which is the canal that sperm follows," Newman answers. "If you have no Y chromosome, then certain hormones are released that say, 'Okay, we'll set up this child's breast tissue to develop at puberty so that she will be able to produce milk.' Men didn't [secrete those hormones], so we don't usually have breast tissue."

"Actually a significant number of boys around the age of puberty do develop breasts," he continues, "so the tissue is there, but it regresses." In short, men may not have full-fledged breasts but they certainly can lactate, under extreme circumstances.

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Babies Exposed to Classical Music End Up Smarter

by Nikhil Swaminathan

The phrase "Mozart Effect" conjures an image of a pregnant woman who, sporting headphones over her belly, is convinced that playing classical music to her unborn child will improve the tyke's intelligence. But is there science to back up this idea, which has spawned a cottage industry of books, CDs and videos?

A short paper published in *Nature* in 1993 unwittingly introduced the supposed Mozart effect to the masses. Psychologist Frances Rauscher's study involved 36 college kids who listened to either 10 minutes of a Mozart sonata in D-major, a relaxation track or silence before performing several spatial reasoning tasks. In one test—determining what a paper folded several times over and then cut might look like when unfolded—students who had listened to Mozart seemed to show significant improvement in their performance (by about eight to nine spatial IQ points).

Rauscher—whose work, unlike most scientists, is sometimes cited on the liner notes of CDs—remains puzzled as to how this narrow effect of classical music extended from a paper-folding task to general intelligence and from college students to children (and fetuses). "I think parents are very desperate to give their own children every single enhancement that they can," she surmises.

In addition to a flood of commercial products in the wake of the finding, in 1998 then-Georgia governor Zell Miller mandated that mothers of newborns in the state be given classical music CDs. And in Florida, day care centers were required to pipe symphonies through their sound systems.

A 2004 Stanford study tracked the media's coverage of Rauscher's study relative to other studies published in *Nature* around the same period. In the U.S.'s top 50 newspapers, her paper, titled "Musical and Spatial Task Performance," was cited 8.3 times more often than the second-most popular paper (co-authored by famed astronomer Carl Sagan).

"It seems to be a circumscribed manifestation of a widespread, older belief that has been labeled 'infant determinism,' the idea that a critical period early in development has irreversible consequences for the rest of a child's life," the researchers wrote in their analysis. "It is also anchored in older beliefs in the beneficial powers of music."

Some still argue for such musical powers. "Music has a tremendous organizing quality to the brain," notes Don Campbell, a classical musician who has written more than 20 books on music, health and education, including *The Mozart Effect*® and *The Mozart Effect*® *for Children*. Referencing French physician Alfred Tomatis's work in music therapy on children with dyslexia, attention-deficit disorders and autism in the mid-20th century, he believes music that's not highly emotional or overly rhythmic has a multilayered influence on the individual, from modulating mood to alleviating stress. "I know it improves our ability to be intelligent," he adds.

But in 1999 psychologist Christopher Chabris, now at Union College in Schenectady, N.Y., performed a meta-analysis on 16 studies related to the Mozart effect to survey its overall effectiveness. "The effect is only one and a half IQ points, and it's only confined to this paper-folding task," Chabris says. He notes that the improvement could simply be a result of the natural variability a

person experiences between two test sittings.

Earlier this year, the Federal Ministry of Education and Research in Germany published a second review study from a cross-disciplinary team of musically inclined scientists who declared the phenomenon nonexistent. "I would simply say that there is no compelling evidence that children who listen to classical music are going to have any improvement in cognitive abilities," adds Rauscher, now an associate professor of psychology at the University of Wisconsin–Oshkosh. "It's really a myth, in my humble opinion."

Rather than passively listening to music, Rauscher advocates putting an instrument into the hands of a youngster to raise intelligence. She cites a 1997 University of California, Los Angeles, study that found, among 25,000 students, those who had spent time involved in a musical pursuit tested higher on SATs and reading proficiency exams than those with no instruction in music.

Despite its rejection by the scientific community, companies like Baby Genius continue to peddle classical music to parents of children who can purportedly listen their way to greater smarts.

Chabris says the real danger isn't in this questionable marketing, but in parents shirking roles they are evolutionarily meant to serve. "It takes away from other kinds of interaction that might be beneficial for children," such as playing with them and keeping them engaged via social activity. That is the key to a truly intelligent child, not the symphonies of a long-dead Austrian composer.

--Originally published: Scientific American Online September 13, 2007.

Men Have a Biological Clock

by Anne Casselman

The female biological clock—its tick-tock marking the decline of fertility that grows louder as a woman reaches middle age—is deeply ingrained in popular consciousness. Take this scene from the film *Bridget Jones's Diary*: Bridget's Uncle Geoffrey reminds her that as a career girl she "can't put it off forever," alluding to her declining fertility. His wife Una chimes in: "tick-tock, tick-tock," her finger wagging like a metronome.

The biological clock, although just a metaphor, refers to a real phenomenon: Women over 35 years of age are only half as likely to become pregnant in the most fertile part of their menstrual cycle than women younger than 26.

So do men suffer from the same thing?

"For women, a biological clock is a decline in fertility and an increased chance of having genetically abnormal babies as they age," says Harry Fisch, director of New York City's Male Reproductive Center and author of *The Male Biological Clock: The Startling News About Aging, Sexuality, and Fertility in Men*. "And that's exactly what's happening with men."

So how did Indian farmer Nanu Ram Jogi sire a healthy child at the age of 90 in 2007? Such a feat would be impossible for a woman, even in an age when Carmela Bousada, 67, gave birth to twins in January 2007 after lying about her age to the doctors who gave her in vitro fertilization. Whereas fertility declines along with testosterone levels as men age, it doesn't drop to zero.

Still, Jogi is definitely the exception rather than the rule. One study found that the odds of fatherhood for those under the age of 30 was 32.1 percent compared with 20 percent over the age of 50, signifying a 38 percent drop in male fertility across that age gap.

One study examined 97 men between the ages of 22 and 80 and found that as they aged their semen volume decreased by 0.001 ounce (0.03 milliliter) per year from an average total of 0.09 ounce (2.7 milliliters) and their "total progressively motile sperm count"—a rough index for the fertility potential of one's sperm based on its movement—decreased about five percent with each year they aged.

Fisch and his colleagues have also found that the children of women over 35 whose babies' fathers were also of that age were more likely to have Down's syndrome than offspring whose fathers were younger.

In other studies, older men were more likely to father children with mental illness or other deficits. Roughly 11 children out of a thousand conceived by men over age 50 developed schizophrenia compared with under three children out of a thousand for fathers under 20 in one study from the *Archives of General Psychiatry*. And the children of men 40 years or older were nearly six times more likely to have autism spectrum disorders than kids begot by men under 30.

So do men's sperm get staler over time? To maintain sperm levels, cells known as germ cells must

continue dividing. After all, men find ways to dispose of sperm—ahem—and once ejaculated they only survive for several days. By the age of 50, these germ cells will have divided 840 times. Each one of those divisions is an opportunity for something to go wrong. "There's more of a chance to have genetic abnormalities the more the cells divide," Fisch says. In sperm these mutations dot the genes with changes in the basic structure of the DNA—and can lead to problems in the resulting offspring.

Bioengineer Narendra Singh of the University of Washington in Seattle and his colleagues compared the sperm of men of different ages. Sure enough, sperm in men older than 35 had more DNA damage than that from younger men. And although unhealthy sperm are supposed to commit cell suicide, some of the sperm they looked at had lost that ability to "take one for the team"—meaning they'd be around to fertilize an egg. "This may lead to offspring with defective DNA, which may translate to mental and physical defects," Singh says.

Can men prevent this damage? No, but they may be able to mitigate it. There are factors within men's control that can accelerate adverse effects: alcohol, smoking, drugs and environmental pollution—even coffee consumption. So avoid them, says Singh.

Still, even after correcting for various lifestyle factors, the DNA of sperm are increasingly damaged with advancing age.

"The question is, can we reverse the [male] biological clock?" asks Fisch, who is studying various ways to keep sperm healthy.

Perhaps Bridget Jones's Uncle Geoffrey and Aunt Una should have chastised her love interest, Mark Darcy, too, for procrastinating procreation. That "tick-tock, tick-tock," it would seem, applies to both sexes.

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SECTION 3

The Environment: Earth and Space

If the Sky Is Green, Run for Cover—a Tornado Is Coming

by Meredith Knight

If the sky turns green during a thunderstorm, gather up your pets and other loved ones and head for the cellar, a twister is on the way. So goes the common wisdom in much of the central U.S.—and other tornado-prone regions in the world, like Australia—when faced with a threatening sky (although some swear green means hail). Scientifically speaking, however, little evidence supports either the tornado or hail claims, though there is some evidence for green thunderstorms.

Over the past 15 years, a small group of scientists have weathered the elements working on green thunderstorms as a pet project, publishing a handful of articles in meteorological journals. All point to the existence of green skies with severe thunderstorms but no direct connection to tornadoes or hail can be made.

"Green skies are associated with severe weather," says physicist and occasional green thunderstorm guru Craig Bohren at Pennsylvania State University. "In areas where tornados are common, they are said to be the cause of green storms. Or you will be told, often with considerable vehemence, that hail causes the greenness. Both explanations are easily refuted by observations."

The first question researchers faced: Is a green sky real, or just an optical illusion caused by light reflected off the ground and back up into the sky, as some green sky dissenters suggest? Frank Gallagher, now a meteorologist for the U.S. Army at Dugway Proving Ground in Utah, tackled this issue for his thesis at the University of Oklahoma. He joined a tornado-chasing research team called VORTEX and recorded the wavelengths of light coming from storms in Texas and Oklahoma using a spectrophotometer, a tool about the size of an old video camera that can measure the color and intensity of light.

Gallagher found that the dominant wavelength of light was green in several severe thunderstorms and that the color was independent of the terrain underneath the storm. As meteorology professor William Beasley, Gallagher's advisor at Okalahoma, put it, "[He] measured green wavelengths of light over a green wheat field and over freshly plowed fields with red-brown Oklahoma dirt."

Threatening green skies during a thunderstorm also proved entirely independent of the type of severe weather that came with it. Gallagher measured hailstorms where the dominant wavelength of light was green as well as hailstorms where it was the typical gray-blue color of thunderstorms. Tornado-producing storms proved similarly divorced from any particular sky color, other than dark.

Researchers remain undecided about the exact mechanisms that cause the sky to appear green in certain thunderstorms, but most point to the liquid water content in the air. The moisture particles are so small that they can bend the light and alter its appearance to the observer. These water droplets absorb red light, making the scattered light appear blue. If this blue scattered light is set against an environment heavy in red light—during sunset for instance—and a dark gray thunderstorm cloud, the net effect can make the sky appear faintly green. In fact, green thunderstorms are most commonly reported in the late afternoon and evening, according to Beasley.

In a paper published in the *Journal of Applied Meteorology*, Gallagher also suggested that green

thunderstorms might occur more frequently than thought. Because it gets quite dark during thunderstorms, the purity of light may be too poor for observers to see the color on most occasions.

Other research on green thunderstorms is limited and not well funded. As Penn State's Bohren says, this is "not exactly a hot topic of research. Indeed, being curious about them can be hazardous to one's career." For example, his small grant from the National Science Foundation for the portable spectrophotometer Gallagher used was derided by then Speaker of the House Newt Gingrich's office and Richard Pombo, then a Republican congressman from California, who denounced Bohren in the *Congressional Record*. (Of course, neither politician hailed from "tornado alley.")

Joshua Wurman at the Center for Severe Weather Research in Boulder, Colo., agrees: "I wouldn't call [the green sky] one of the burning issues in tornado science." Nevertheless, the research that is out there suggests that the green colored sky some might observe during a severe thunderstorm does have limited predictive power for those who live in areas where severe weather occurs, like Dorothy —and her little dog, too.

--Originally published: Scientific American Online June 14, 2007.

Smog Creates Beautiful Sunsets

by Coco Ballantyne

Picture twilight in Los Angeles: the city's labyrinth of eight-lane freeways is jammed with millions of cars, engines burping pollutants into the air. The people in those cars may be drowning in a sea of smog, but they at least can take solace in seeing a scarlet sunset blazing across the horizon.

According to urban legend, air pollution enhances the beauty of a sunset. And pollution does indeed change the appearance of sundown, but whether it tips it in the direction of beauty is a matter of personal taste—and the overall amount of that pollution in the air.

Be it the azure of high noon or the orange glow of dusk, the colors of the sky result from sunlight interacting with molecules in the air, primarily nitrogen and oxygen, which cause it to be deflected in all directions, a phenomenon called Rayleigh scattering. All wavelengths of light are scattered, but they are not scattered equally. According to John W. S. Rayleigh's approximate scattering law, colors with shorter wavelengths are scattered the most: violet, followed by blue, then green, and so on.

During the day, when the sun is directly overhead, light travels only a short distance through a relatively thinner section of the atmosphere. But as the sun edges toward the horizon, the light must travel increasingly longer paths and is scattered by more air molecules. By the time it reaches the end of this journey (our eyes), "most of the blue has been scattered out of that beam" explains Stephen Corfidi, a meteorologist at the National Oceanic & Atmospheric Administration (NOAA). What remains are the warmer hues of yellow, orange and red, which blend into a yellowish-orange sunset.

Yet, scattering by nitrogen and oxygen can only explain how sunsets can be orange and perhaps redd*ish*, not how the sky can blush blood red. "In an atmosphere with no junk at anytime, you'll never get a sunset that would make someone with normal color vision say, 'Wow that's red!'" says Craig Bohren, professor emeritus of meteorology at Pennsylvania State University. "It is certainly true that the 'pollution' results in redder sunsets."

To get a red sky, you need aerosols, explains A. R. Ravishankara, director of chemical sciences at the NOAA Earth System Research Laboratory in Boulder, Colo. Aerosols are solid or liquid particles suspended in the air that originate from both natural processes and human activity.

Natural aerosols come from forest fires, mineral dust kicked up by sandstorms, sea spray and volcanic eruptions, among other things. Volcanoes, which have produced some of the most spectacular sunsets in history, can inject sulfuric acid droplets into the stratosphere, the layer of the atmosphere between 10 to 35 miles in altitude. These droplets can be swept across the globe, painting brilliant crimson twilights wherever they go. Following the 1883 eruption of Indonesia's Krakatoa, brilliant sunsets appeared around the world, one of which is said to have inspired Norwegian artist Edvard Munch's painting, *The Scream*.

But "in a large city, you can ignore natural aerosol products for the most part" because the number of aerosols produced by human activity far exceeds natural sources, says Sergey Nizkorodov, a chemist at the University of California, Irvine. Human-generated aerosols can enter the atmosphere directly, as is the case with soot emitted by internal combustion engines in cars and trucks, he

explains. Aerosols are also produced when molecules in the gaseous state enter the atmosphere and react with other chemicals, he adds. A classic case: burning fossil fuels releases sulfur dioxide gas into the air, which then turns into sulfuric acid aerosols.

Most particles suspended above cities scatter radiation, preferentially removing the cooler violets and blues in the spectral palette and enhancing the red, Nizkorodov says. In this sense, these particles scatter light much the same as do oxygen and nitrogen molecules.

"Molecules and small particles scatter the same way as long as the particle is sufficiently small," Bohren says. If the particle is small compared with the wavelengths of visible light, it will scatter short wavelengths, such as blues and violets, more than long wavelengths, such as red. Many man-made aerosols are small enough to meet this criterion, so they contribute to the deep crimson sunsets of Los Angeles and other polluted cities across the globe.

However, "at some point, the air pollution is so bad, and the sky is so saturated, you don't even see the sun clearly anymore," Nizkorodov says. For example, the sunset can appear bright but washed out when large numbers of big particles accumulate in the troposphere, the layer of the atmosphere closest to the ground. Aerosols that are close in size or larger than the wavelengths of visible light tend to scatter all colors indiscriminately, increasing the overall brightness of the sky but dampening color contrast.

"Particles of any kind, even much smaller than the wavelength of visible light, will, as a rule, make the sky brighter but at the expense of its purity of color," Bohren says, noting that the effect is more pronounced when there is a high concentration of large aerosols. So, although aerosols may make a sunset red, excess pollution will also dampen the overall sunset experience. In fact, the transition from day to night might be a whole lot peachier—and healthier—without all that atmospheric flotsam.

--Originally published: Scientific American Online July 12, 2007.

South of the Equator Toilets Flush and Tornadoes Spin Clockwise

by Robynne Boyd

Weather isn't always predictable. If it were, daily forecasts would be spot-on, hurricanes anticipated, and picnics safe from abrupt summer downpours. Instead, climate systems are complex, and tornadoes are no exception. So, whereas guessing the direction of a tornado's torque is possible, like any weather prediction the forecast will only be correct most of the time.

It's true that tornadoes tend to revolve counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. However, according to research meteorologist Richard Rotunno of the U.S. National Center for Atmospheric Research in Boulder, Colo., the opposite has also occurred. There has even been the occasional appearance of both counterclockwise and clockwise rotating tornadoes under the same thunderstorm. These deviations undercut the common misperception that the direction of a tornadoes' spin results from the Coriolis force.

To set the record straight, Rotunno explains that the Coriolis force only has a significant influence on the spin direction of Earth's largest atmospheric and oceanographic circulation systems, such as the Gulf Stream, jet stream, trade winds and hurricanes. Earth's rotation around its axis causes this effect, making Northern Hemisphere winds deflect to the right and those in the Southern Hemisphere deflect to the left. It is also why an airplane flying from Anchorage to Miami must consider the Earth's counterclockwise rotation (as seen from the North Pole) to land at its destination, instead of splashing into the Gulf of Mexico.

The Coriolis force isn't, however, omnipotent, compelling all currents great and small to spin counterclockwise when north of the equator and clockwise to its south. Though many people have seen videos of toilets flushing in Australia and the U.S. that swirl in opposite directions, these experiments are based on luck and, perhaps not surprisingly, the toilets' varying designs. Pranksters have even gone so far as to blame the Coriolis effect for hair curling in a certain direction.

Despite the large amount of misinformation, toilets—and even tornadoes—are too small to be affected by the Coriolis, whose force would only begin to directly influence a storm's swirling mass if it were approximately three times larger than the supercell storm systems that typically generate tornadoes.

"Tornadoes are only indirectly influenced by the Coriolis force," says meteorologist Harold Brooks of the National Oceanic & Atmospheric Administration's National Severe Storms Laboratory in Norman, Okla. The majority of tornadoes happen in "tornado alley," in the Great Plains of the U.S., but they can happen anywhere in the world, including southern Brazil, northeastern Argentina and Bangladesh. These violently roiling columns of air originate from parent thunderstorms called supercells. In the U.S., supercells form when dry polar air from Canada meets moist tropical air from the Gulf of Mexico, causing the warm air to rapidly rise.

The upwelling current of air within a thunderstorm is referred to as an updraft. "If sufficient vertical wind shear (the increase of wind speed with height) exists, this updraft will rotate," Brooks says.

"Tornadoes usually rotate in the same direction as the thunderstorm they're associated with." Therefore, if the warm winds blowing north from the equator meet cool upper-level winds out of the west, the tornado will rotate counterclockwise. And if the warm equatorial winds blow to the south and clash with aloft winds, a tornado will rotate clockwise.

This is because in both hemispheres, upper-level winds blow out of the west due to planetary rotation. These winds are Coriolis's subtle claim to a tornado's torque.

Although understanding Coriolis's weak influence over the direction of a tornado's spin seems feasible, fully grasping how tornadoes function may not be. And predicting exactly when and where tornadoes will occur-and which way they will spin-seems even less so. Uncertainty may be the only certainty of weather.

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The Earth Is Not Round

by Charles Q. Choi

As countless photos from space can attest, Earth is round—the "Blue Marble," as astronauts have affectionately dubbed it. Appearances, however, can be deceiving. Planet Earth is not, in fact, perfectly round.

This is not to say Earth is flat. Well before Columbus sailed the ocean blue, Aristotle and other ancient Greek scholars proposed that Earth was round. This was based on a number of observations, such as the fact that departing ships not only appeared smaller as they sailed away but also seemed to sink into the horizon, as one might expect if sailing across a ball says geographer Bill Carstensen of Virginia Tech in Blacksburg.

Isaac Newton first proposed that Earth was not perfectly round. Instead, he suggested it was an oblate spheroid—a sphere that is squashed at its poles and swollen at the equator. He was correct and, because of this bulge, the distance from Earth's center to sea level is roughly 21 kilometers (13 miles) greater at the equator than at the poles.

Instead of Earth being like a spinning top made of steel, explains geologist Vic Baker at the University of Arizona in Tucson it has "a bit of plasticity that allows the shape to deform very slightly. The effect would be similar to spinning a bit of Silly Putty, though Earth's plasticity is much, much less than that of the silicone plastic clay so familiar to children."

Our globe, however, is not even a perfect oblate spheroid, because mass is distributed unevenly within the planet. The greater a concentration of mass is, the stronger its gravitational pull, "creating bumps around the globe," says geologist Joe Meert at the University of Florida in Gainesville.

Earth's shape also changes over time due to a menagerie of other dynamic factors. Mass shifts around inside the planet, altering those gravitational anomalies. Mountains and valleys emerge and disappear due to plate tectonics. Occasionally meteors crater the surface. And the gravitational pull of the moon and sun not only cause ocean and atmospheric tides but earth tides as well.

In addition, the changing weight of the oceans and atmosphere can cause deformations of the crust "on the order of a centimeter or so," notes geophysicist Richard Gross at the Jet Propulsion Laboratory in Pasadena, Calif. "There's also postglacial rebound, with the crust and mantle that were depressed by the huge ice sheets that sat on the surface during the last ice age now rebounding upward on the order of a centimeter a year."

Moreover, to even out Earth's imbalanced distribution of mass and stabilize its spin, "the entire surface of the Earth will rotate and try to redistribute mass along the equator, a process called true polar wander," Meert says.

To keep track of Earth's shape, scientists now position thousands of Global Positioning System receivers on the ground that can detect changes in their elevation of a few millimeters, Gross says. Another method, dubbed satellite laser ranging, fires visible-wavelength lasers from a few dozen ground stations at satellites. Any changes detected in their orbits correspond to gravitational

anomalies and thus mass distributions inside the planet. Still another technique, very long baseline interferometry, has radio telescopes on the ground listen to extragalactic radio waves to detect changes in the positions of the ground stations. It may not take much technology to understand that Earth is not perfectly round, but it takes quite a bit of effort and equipment to determine its true shape.

--Originally published: Scientific American Online April 12, 2007.

Black Holes Sing

by John Matson

In the dark heart of the Perseus galaxy cluster, 300 million light-years from Earth, a supermassive black hole has been singing the same note for 2.5 billion years. Its tone registers 57 octaves below middle C and, according to scientists at NASA's Chandra X-Ray Center, is a resounding B-flat. Yet, how is this possible in the vacuum of space?

Sound requires a medium, such as water or air, to travel. Here on Earth a sound wave moves from its origin by causing the surrounding air molecules to vibrate. The vibrations pass from one molecule to another; when they hit an ear, they are understood as noise. But because neither air nor water nor much of anything else exists in the majority of vast reaches of space, it is difficult for sound to travel there.

It takes a supermassive black hole—like a robust opera diva—to sing a resonant note in space. These monstrous celestial objects range from hundreds of thousands to tens of billions times our sun's mass and are commonly found in the center of active galaxies. For example, Sagittarius A*—a supermassive black hole—sits at the center of our own galaxy, the Milky Way.

Black holes are notorious for their gravitational might, which is so strong that nothing can escape, according to conventional wisdom. But this isn't quite correct—some matter does. A black hole's gravity pulls a mishmash of matter and energy into its surrounding accretion disk—a ringlike structure formed by gas and dust. But some of this matter is violently expelled from the black hole's poles as "relativistic jets." These jets surge into the scorching gas surrounding the hole and generate pockets in the otherwise uniform cloud.

"Sound waves are pressure waves. And black holes, or at least their relativistic jets, can generate enormous sound waves, which then propagate through surrounding galactic gas," explains astronomer Steven Allen, a professor of physics at Stanford University who studies the Perseus galaxy cluster. "When relativistic jets, which contain material moving at close to the speed of light, slam into the hot gas that pervades giant elliptical galaxies and clusters of galaxies, they beat a 'galactic drum,' as it were." The jet acts as the "stick," whereas the surface of the gas is the "drum."

Although people can't hear these waves (because sound can't travel through the vast vacuum separating this "drum" and us), we can "see" them using x-ray observations. As sound waves spread through the scorching gas in galaxies and galaxy clusters, regions of greater pressure (sound wave peaks) tend to appear brighter in x-rays; fainter regions (troughs) are dimmer.

Chandra x-ray telescope observations of the Perseus Cluster show roughly concentric ripples of brighter and fainter gas, which indicate sound waves. "We can't see the waves moving," Allen says. "The relevant timescales are too long, since the period of the waves is about 10 million years—but we have a clear 'snapshot' of them."

Perseus' black hole is not the universe's sole galactic vocalist. M87, a galaxy that holds one of the universe's most massive black holes, is also known to croon. Although its song isn't as steady as Perseus', it is more involved, with notes as deep as 59 octaves below middle C.

"There's no reason for black holes to sing the same note," says Peter Edmonds, an astrophysicist at the Chandra X-Ray Center. Galaxies that have more matter may provide a deeper sound, because this matter could lead to bigger, but less common eruptions from the black hole. There are bound to be other important factors contributing to a black hole's specific sound, such as the temperature of the gas and its location, but the details aren't well understood, says Edmonds.

Other interstellar objects and events produce sound waves as well, he adds. In fact, the echoes of the big bang have been humming and hissing since shortly after the universe's birth.

According to astronomer Mark Whittle of the University of Virginia, the big bang's sound waves were created during the universe's first 380,000 years when space was still foggy with gas containing free electrons. Once the fog cleared, however, the universe fell silent.

The big bang's ballad is still detectable though, and is described by Whittle as "a descending scream, changing into a deepening roar, with subsequent growing hiss." He adds: "Perhaps most remarkably, within the big bang's sound there is a fundamental tone and a set of harmonics."

Of course, the big bang itself was mute, because it takes time for pressure to act across distances and generate a sound wave. Only later, as the pressure forces crossed regions of outer space and set up sound waves did the latter establish their presence.

Closer to home, the sun has been chanting for billions of years. Convection currents on the solar surface produce pressure waves that travel to the inner corona and back to the surface, causing the surface to broil and vibrate. These deep, three-dimensional sound waves allow scientists to better understand the sun's internal structure.

In fact, the music of the spheres, and even of supermassive black holes, provides insights into the fundamental nature of our universe. Though no living thing on Earth can hear the music of outer space, the cosmos continues its orchestral display. For understanding, scientists watch (and listen) closely—making astronomers the best audience on Earth.

--Originally published: Scientific American Online October 18, 2007.

Liven Up Your Flowers with Vodka and Citrus Sodas

by Ciara Curtin

The day after Valentine's Day, flower bouquets from sweethearts around the world begin to fade. A rose's vibrant red dulls to dried-out brown, and flowers begin to droop. Some say adding a citrus-flavored soda, such as 7-Up or Sprite, or an alcohol like vodka to the vase of water will lengthen the time these flowers remain beautiful.

According to floriculturists, they are right; if the mixture of soda and water is in the correct proportion, a bouquet will remain bright, because the combination provides the flowers with the water and food they need. "The 7-Up formula works really well," says Susan Han, a professor in the plant, soil and insect science department at the University of Massachusetts Amherst. Vodka also works as a flower preservative by interfering with the plant's ripening process but it is less practical to use.

Cut flowers, like those in a bouquet, are separated from their roots and no longer make food for themselves. Instead, their environment provides everything necessary to keep them fresh. Slightly acidic water travels up the stems to the flowers more rapidly than neutral or basic water, keeping the flowers hydrated and fresh. But in addition to water, plants need sugar for food.

This necessary combination of acidic water and sugar describes 7-Up or Sprite, says William Miller, a professor of horticulture at Cornell University. One can of either is loaded with citric acid that lowers the pH (increases the acidity) of the soda and contains about 38 grams of sugar. But, while water and sugar keep the flowers fresh, this mixture also encourages bacterial growth, which can harm the flowers. "So add bleach," Han says. A little bleach kills the bacteria without damaging the flowers.

When brewing this concoction, which is essentially what flower food packets hold, Miller and John Dole, a professor of horticulture at North Carolina State University, recommend one can of water for every can of soda added to the vase. Han, however, prefers a three-to-one ratio of water to soda, along with a few drops of bleach to kill the bacteria.

Vodka has a different effect on a bouquet of flowers: When added to a vase, it preserves them, probably by inhibiting ethylene production, Dole says. Ethylene is a ripening gas emitted by plants that helps them mature. Inhibiting this gas could slow wilting. Vodka, however, is not a very viable preservative. Plants!like many people!can only tolerate small concentrations of alcohol, up to eight percent, Dole explains, and 80-proof vodka from the liquor store is 40 percent alcohol. To be effective rather than harmful, the liquor would need to be dilutedInstead, growers use a more effective preservative, silver thiosulfate, which also inhibits ethylene, he says.

Other flower care strategies can help a bouquet stay beautiful. When the flowers arrive home, half an inch to an inch of the stem should be cut off. This prevents air from being sucked into the stem and creating a blockage in the plant's uptake system, Miller says. Also, removing the ends physically removes any bacteria that might be growing there, he adds. Roughly every three days another inch should be cut from the stem bottoms and the bouquet should be placed in a clean vase. "If you

wouldn't drink out of your vase, don't be putting flowers in it," Dole advises. After fresh food and water are added to the clean vase, the bouquet should be placed in a bright, cool spot.

No matter what efforts are made, of course, over time the flowers will slowly die. "It is perfectly okay to go through and pluck out the dead flowers," Miller says. That way the remaining bouquet looks bright and pretty.

Sodas like 7-Up and Sprite may keep flowers from a sweetheart fresh but what keeps sweethearts fresh is not yet known to science, though vodka and soda might be key ingredients there, too.

--Originally published: Scientific American Online February 14, 2007.

Living People Outnumber the Dead

by Ciara Curtin

The human population has swelled so much that people alive today outnumber all those who have ever lived, says a factoid whose roots stretch back to the 1970s. Some versions of this widely circulating rumor claim that 75 percent of all people ever born are currently alive. Yet, despite a quadrupling of the population in the past century, the number of people alive today is still dwarfed by the number of people who have ever lived.

In 2002 Carl Haub, a demographer at the Population Reference Bureau, a nongovernmental organization in Washington, D.C., updated his earlier estimate of the number of people that have ever existed. To calculate this, he studied the available population data to determine the human population growth rates during different historical periods, and used them to determine the number of people who have ever been born.

For most of history, the population grew slowly, if at all. According to the United Nations' Determinants and Consequences of Population Trends, the first *Homo sapiens* appeared around 50,000 years ago, though this figure is debatable. Little is known about this distant past and how many of us there might have been, but by the time of the agricultural revolution in the Middle East in 9000 B.C., Earth held an estimated five million people.

Between the rise of farming and the height of Roman rule, population growth was sluggish; at less than a tenth of a percent per year, it crawled to about 300 million by A.D. 1. Then the total fell as plagues wiped out large swathes of people. (The "black death" in the 14th century wiped out at least 75 million.) As a result, by 1650 the world population had only increased to about 500 million. By 1800, though, thanks to improved agriculture and sanitation, it doubled to more than one billion. And, in 2002 when Haub last made these calculations, the planet's population had exploded, reaching 6.2 billion.

To calculate how many people have ever lived, Haub followed a minimalist approach, beginning with two people in 50000 B.C.—his Adam and Eve. Then, using his historical growth rates and population benchmarks, he estimated that slightly over 106 billion people had ever been born. Of those, people alive today comprise only 6 percent, nowhere near 75 percent. "[It is] almost surely true people alive today are some small fraction of [all] people," says Joel Cohen, a professor of populations at the Rockefeller and Columbia Universities in New York City.

For this myth ever to be valid there would have to be more than 100 billion people living on Earth. "How cozy," Cohen says. "It just doesn't seem plausible," he adds.

According to UN estimates, approximately 7 billion people are walking on Earth. Recently, the population has been increasing by about 1.2 percent each year, down from the late 1960s peak of a 2.1 percent yearly growth rate. Some industrialized countries, especially France and Japan, have very low birth rates and their populations are actually dwindling, Haub notes. In developing nations populations continue to grow, but some countries, such as India, are experiencing a slowdown in their growth rate.

Cohen doubts that a doubling of today's population, to 13 billion, will occur, never mind approaching anywhere near 100 billion. Not even the U.N.'s highest projection predicts that much growth, he says. For 2050, the world body's estimates range from 7.3 billion to 10.7 billion people. The median, and most likely, projection of 8.9 billion relies on a gradual slowing of the growth rate. And the U.N. predicts the world population will stabilize at 10 billion inhabitants sometime after 2200. At this rate, the living will never outnumber the dead.

--Originally published: Scientific American Online March 1, 2007.

SECTION 4

Technology

NASA Created a Million-Dollar Space Pen

by Ciara Curtin

During the height of the space race in the 1960s, legend has it, NASA scientists realized that pens could not function in space. They needed to figure out another way for the astronauts to write things down. So they spent years and millions of taxpayer dollars to develop a pen that could put ink to paper without gravity. But their crafty Soviet counterparts, so the story goes, simply handed their cosmonauts pencils.

This tale with its message of simplicity and thrift--not to mention a failure of common sense in a bureaucracy--floats around the Internet, hopping from in-box to in-box, and even surfaced during a 2002 episode of the *West Wing*. But, alas, it is just a myth.

Originally, NASA astronauts, like the Soviet cosmonauts, used pencils, according to NASA historians. In fact, NASA ordered 34 mechanical pencils from Houston's Tycam Engineering Manufacturing, Inc., in 1965. They paid $4,382.50 or $128.89 per pencil. When these prices became public, there was an outcry and NASA scrambled to find something cheaper for the astronauts to use.

Pencils may not have been the best choice anyway. The tips flaked and broke off, drifting in microgravity where they could potentially harm an astronaut or equipment. And pencils are flammable--a quality NASA wanted to avoid in onboard objects after the *Apollo 1* fire.

Paul C. Fisher and his company, the Fisher Pen Company, reportedly invested $1 million to create what is now commonly known as the space pen. None of this investment money came from NASA's coffers--the agency only became involved after the pen was dreamed into existence. In 1965 Fisher patented a pen that could write upside-down, in frigid or roasting conditions (down to minus 50 degrees Fahrenheit or up to 400 degrees F), and even underwater or in other liquids. If too hot, though, the ink turned green instead of its normal blue.

That same year, Fisher offered the AG-7 "Anti-Gravity" Space Pen to NASA. Because of the earlier mechanical pencil fiasco, NASA was hesitant. But, after testing the space pen intensively, the agency decided to use it on spaceflights beginning in 1967.

Unlike most ballpoint pens, Fisher's pen does not rely on gravity to get the ink flowing. The cartridge is instead pressurized with nitrogen at 35 pounds per square inch. This pressure pushes the ink toward the tungsten carbide ball at the pen's tip.

The ink, too, differs from that of other pens. Fisher used ink that stays a gellike solid until the movement of the ballpoint turns it into a fluid. The pressurized nitrogen also prevents air from mixing with the ink so it cannot evaporate or oxidize.

According to an Associated Press report from February 1968, NASA ordered 400 of Fisher's antigravity ballpoint pens for the Apollo program. A year later, the Soviet Union ordered 100 pens and 1,000 ink cartridges to use on their Soyuz space missions, said the United Press International. The AP later noted that both NASA and the Soviet space agency received the same 40 percent discount for buying their pens in bulk. They both paid $2.39 per pen instead of $3.98.

The space pen's mark on the Apollo program was not limited to facilitating writing in microgravity. According to the Fisher Space Pen Company, the *Apollo 11* astronauts also used the pen to fix a broken arming switch, enabling their return to Earth.

Since the late 1960s American astronauts and Russian cosmonauts have used Fisher's pens. In fact, Fisher has created a whole line of space pens. A newer pen, called the Shuttle Pen, was used on NASA's space shuttles and on the Russian space station, Mir. Of course, you don't have to go to space to get your hands on a space pen--earthbound folks can own one for the low, low price of $50.00.

--Originally published: Scientific American Online December 20, 2006.

White Computer Screens Consume More Energy Than Black Ones

by Larry Greenemeier

The green computing movement demands that all computer users shed the energy-wasting practices to which they've grown accustomed—so you decide that you're going to power down your PC at night, invest in an Energy Star–approved laptop, and only visit Web pages that eschew white space in favor of ostensibly more energy-efficient black backgrounds.

Before you tune out and turn off, you should know that black isn't necessarily the new green. Because computer monitors come in a variety of shapes and sizes, and not all monitors create black and white the same way, there's no proof that, on the whole, increased usage of black images would save more energy than the continued use of white ones. In fact in newer liquid-crystal display, or LCD, monitors white is actually slightly more energy efficient than black.

The notion that black screens save electricity certainly makes sense when you're talking about cathode-ray tube, or CRT, technology that works by moving an electron beam back and forth across the back of the screen. "The front screen is covered with red, blue and green phosphors," says Bill Schindler, vice president of electrical engineering for Panasonic Plasma Display Laboratory of America. To produce white, the electron beam is directed at the phosphors. However, "when the screen is black, you don't have to fire the beam," he adds.

CRT monitors, which until some years ago were the predominant models among PC users, consume more power when a computer screen is white. To confirm this, Schindler measured the energy output of an 18-inch (45.7-centimeter) CRT monitor and found it used 102 watts when the screen was white but only 79 watts when the display was black.

This is not the case, however, with LCD monitors, which have no phosphors and represent the lion's share of every new monitored purchased in the developed world, including those used by laptops. Instead, LCD displays rely on an array of thin-tube fluorescent bulbs that provide a constant source of light to create a white screen. To make it black, LCDs rely on a diffuser to block this light. As a result, LCDs use more energy than CRTs to display a black screen. Measuring a 17-inch (43-centimeter) LCD monitor, Schindler found that white required 22.6 watts, while black came in a tad higher at 23.2 watts. With a 20-inch (50.8-centimeter) LCD, black required 6 percent more energy than white.

One of the most visible manifestations of the belief that black screens save energy is *Blackle*, an online search engine whose Web site is cast almost entirely in black. Created by Heap Media, *Blackle* exists "to remind people of the need to take small steps every day to save energy," says Blackle founder Toby Heap, who launched the site in January. "I do not expect the energy savings from Blackle to change the world on their own, but the point of *Blackle* is that every little bit counts."

One of the key arguments in favor of black screens is a 2002 research study produced by Lawrence Berkeley National Laboratory entitled "Energy Use and Power Levels in New Monitors and Personal Computers." The report indicates that "a given monitor requires more power to display a white (or

light) screen than a black (or dark) screen." Indeed, that study reports that black screens consistently require less energy than white screens, regardless of whether the monitor is a CRT or LCD.

"It depends on the resting state of the LCD as to whether they require energy to stop light or to allow light to pass through," Heap explains. "This is why screen tests show that some CCFL (cold cathode fluorescent lamp) LCD screens save energy and some use a bit more. All of the scientific test data we have come across shows a slight saving on black LCD screens, which suggests that the rest state on many LCD screens does not allow light through." Heap also points out that a large number of *Blackle* users come from India and South America, where CRTs are still commonly sold.

Even though *Google* isn't tied to *Blackle* other than powering its search engine, Google green energy czar Bill Weihl in August posted a blog disputing the notion of black as the new green. "We applaud the spirit of the idea, but our own analysis as well as that of others shows that making the *Google* homepage black will not reduce energy consumption," he wrote. "To the contrary, on flat-panel monitors (already estimated to be 75 percent of the market), displaying black may actually increase energy usage."

New advances in LCD technologies could eventually validate the belief that black is better. Newer types of LCD include a dynamic dimming capability that changes the strength of the backlight based on the image being displayed. Heap also points out that many of the new monitor technologies such as LCDs backlit with light-emitting diodes (LED), plasma screens and organic LED screens do not have a constant backlight "so we will see larger savings with *Blackle* as these new monitors replace the CCFL LCDs," he says.

In the meantime, the world is evenly split between CRT and LCD monitors, totaling roughly 405 million and 401 million respectively in 2007, according to iSuppli data. So if you're still toiling away in front of a hefty CRT monitor that takes up three-quarters of your desk, then black screens will save you some energy. For those who've graduated to thinner LCD models, black screens are actually sucking up more energy then their white counterparts.

--Originally published: Scientific American Online September 27, 2007.

Leaving Fluorescent Lights on Saves Energy

by John Matson

So you bought a compact fluorescent lightbulb in a bid to be green. Such bulbs are vastly more energy-efficient than traditional incandescents and screw into standard sockets. Should you treat them like their older cousins?

After all, four- and eight-foot- (1.2- and 2.4-meter-) long tubular bulbs common in more institutional settings are sometimes left on permanently, perhaps due to their slow, flickering start-ups. The thinking is that the boost of energy such bulbs require to power up means that it might be best to keep them on when leaving a room, rather than subjecting them to the stress of a restart on your return.

Turns out, however, that power surge is so brief that its energy draw doesn't amount to much: the equivalent of a few seconds or so of normal operation, according to U.S. Department of Energy estimates. In other words, from a strict energy-conservation standpoint, it's almost always beneficial to shut off fluorescents when leaving the room—the start-up energy is offset by the power saved in even the briefest outages.

But what about the wear and tear on the bulb itself? Being too switch-happy reduces the operating life of the lamp, and given that newer fluorescents are still a few times more expensive than old-fashioned incandescents, it makes sense to forestall burnouts. There are also real environmental impacts of their production and disposal to consider.

A simple rule of thumb that balances both concerns is to shut off fluorescents if you're planning to leave a room for more than five minutes, according to Francis Rubinstein, a staff scientist in the Building Technologies Department at Lawrence Berkeley National Laboratory's Environmental Energy Technologies Division. Mary Beth Gotti, manager of the GE Lighting & Electrical Institute in Cleveland, agrees. For all practical purposes, "it almost always makes sense to turn the lights off," Gotti says. "From an environmental standpoint, the best way to save energy is to turn off the things that you're not using."

Rubinstein notes that, even for fluorescents, the cost of electricity over a bulb's lifetime far outpaces the cost of the bulb itself. "Even if you switch on and off a fluorescent light frequently," he says, "the slight reduction in lamp life is a small effect relative to the energy savings you accomplish by being a good citizen." Gotti adds that the reduction in lamp life from frequent on-and-off switching can often be counterbalanced by the extension of "calendar life"—the actual passage of time between lightbulb replacements—that results from using the bulb for fewer hours.

That sort of calculation will probably become more common as compact fluorescent lightbulbs come down in price, cast more pleasant light and, most importantly, force their power-hungry competitors from store shelves. The Australian government will phase out the sale of traditional incandescents in that country by 2010, and the U.S. Congress has effectively mandated the same ban domestically by 2012. But whereas that new fluorescent bulb is sure to lower utility bills in your home, the real energy-crunch savior has been there all along: the light switch.

--Originally published: Scientific American Online March 27, 2008.

Helmets Are Car Magnets for Cyclists

by Nikhil Swaminathan

Spring is in full swing now, and a number of the straphangers (read: subway riders) in New York City, as well as citizens in other locales, are getting new tubes and tires and dragging their bikes out of storage. Bicycle riding is the skill you reportedly never forget, but there's a raging debate about whether or not you should forget your helmet when you hop on your two-wheeler.

In September 2006, a plucky psychologist at the University of Bath in England announced the results of a study in which he played both researcher and guinea pig. An avid cyclist, Ian Walker had heard several complaints from fellow riders that wearing a helmet seemed to result in bike riders receiving far less room to maneuver—effectively increasing the chances of an accident. So, Walker attached ultrasonic sensors to his bike and rode around Bath, allowing 2,300 vehicles to overtake him while he was either helmeted or naked-headed. In the process, he was actually contacted by a truck and a bus, both while helmeted—though, miraculously, he did not fall off his bike either time.

His findings, published in the March 2007 issue of *Accident Analysis & Prevention*, state that when Walker wore a helmet drivers typically drove an average of 3.35 inches closer to his bike than when his noggin wasn't covered. But, if he wore a wig of long, brown locks—appearing to be a woman from behind—he was granted 2.2 inches more room to ride.

"The implication," Walker says, "is that any protection helmets give is canceled out by other mechanisms, such as riders possibly taking more risks and/or changes in how other road users behave towards cyclists." The extra leeway granted to him when he pretended to be a woman, he explains, could result from several factors, including drivers' perceptions that members of the fairer sex are less capable riders, more frail or just less frequent bikers than men.

Randy Swart, founder of the Bicycle Helmet Safety Institute (BHSI), says that studies such as Walker's run the risk of misleading cyclists as to the effectiveness of helmets. "The cars were giving him, on average, a very wide passing clearance already," he explains, noting that most vehicles typically stayed well over three feet from the bikes, rendering the 3.35-inch discrepancy to be insignificant. "If you really want the greatest passing distance, you should wobble down the road," looking as inept as possible, he adds.

Walker actually reanalyzed his data recently to counter this line of reasoning. "I assessed the number of vehicles coming within one meter [roughly 3.3 feet] of the rider, on the principle that these are the ones that pose a risk," he says. "There were 23 percent more vehicles within this one-meter danger zone when a helmet was worn, suggesting a real risk."

Dorothy Robinson, a patron of the Bicycle Helmet Research Foundation and a senior statistician at the University of New England in Armidale, Australia, published a 2006 review article in the *BMJ (British Medical Journal)* about regions in Australia, New Zealand and Canada that introduced legislation that spurred an over 40 percent increase in bicycle helmet use among their populaces. The newly instituted laws, she found, did not have a significant effect on bicycle accidents resulting in head injuries, the primary purpose of the gear. Her conclusion was "helmets are not designed for

forces often encountered in collisions with motor vehicles" as well as that they "may encourage cyclists to take more risks or motorists to take less care when they encounter cyclists."

Coincidentally, around the same time as Walker announced his results, New York City released a report on bicycle deaths and injuries: 225 cyclists died between 1996 and 2005 on New York streets; 97 percent of them were not wearing helmets. Of these deaths, 58 percent are known to involve head injury, but the actual number could be as high as 80 percent. Comparing the helmet to a seat belt in a car, Swart of the BHSI says, "When you do have that crash, you better have it on."

Walker, whose much-publicized report may inspire a new generation of bareheaded riders, won't make any specific recommendations to other cyclists (and neither will *Scientific American*), though he notes that when it comes to riding in traffic, motorists are the real problem. "If people read the research and decide a helmet makes them safer, they should wear one; if they read the research and decide it doesn't, perhaps they don't need to," Walker says, adding the caveat, "But they do need to read the research!" And watch out for cars.

--Originally published: Scientific American Online May 10, 2007.

Premium Gasoline Delivers Premium Benefits to Your Car

by David Biello

Premium gasoline must be premium for a reason. After all, one of that adjective's definitions is "a high value or a value in excess of that normally or usually expected," according to *Merriam-Webster's Collegiate Dictionary*. Therefore, premium gasoline must be better, otherwise why would it be called premium? The answer to that question lies in the dynamics of the typical internal combustion engine, the process of refining gasoline from oil, and another definition of "premium"—this one from its noun form: "a sum over and above a regular price paid chiefly as an inducement or incentive."

First and foremost, premium gas really is a better fuel in terms of the power it provides in the right engine. All gasoline is a heady brew of many different hydrocarbon molecules, ranging from heptane (seven carbon atoms and 16 hydrogens) to decane (10 carbons and 22 hydrogens) and beyond. The hydrocarbon clearly identified on the pump is octane (eight carbon atoms and 18 hydrogens). This number, however, is not a measure of the percentage of octane actually in the gas itself. Rather, it is a measure of how that gasoline compares with a pure mixture of octane and heptane. At special laboratories across the globe, chemists concoct such reference fuels and then use them in comparison with refined gasoline following the dictates of standardized measures. "The American Society of Testing and Materials has this thick document on how you determine octane rating with this specialized one-cylinder engine," explains Joseph Shepherd, a mechanical engineer at the California Institute of Technology. "The higher the number the harder it is to have knock."

"Knock"—an unregulated explosion in a chamber designed for highly regulated combustion—is the bane of an internal combustion engine. During the four-stroke cycle of a typical car motor, the piston drops in the cylinder, allowing it to fill with a mixture of gasoline and air. The piston then moves up again, compressing the fuel mix and, when it reaches the top, the spark plug ignites the explosive vapor, driving the piston down again. As the piston returns to the top of the cylinder it expels what remains of the spent fuel out through the exhaust valves and the whole process starts again. Knock occurs when the compression of the fuel and air mixture alone, and not the spark plug, sets off an explosion. This results in a very loud noise and a lot of vibrations in the engine itself; "it's very bad for engines mechanically," Shepherd notes, driving the piston down before it has reached the top of its cycle. Each hydrocarbon molecule behaves differently under pressure, but octane resists the temptation to explode better than its volatile cousin heptane. "You rate the gasoline about how it knocks compared to this reference mixture," explains William Green, a chemist at the Massachusetts Institute of Technology. "One's that don't knock very much are the premium." That is, they behave in an engine as if they have a high proportion of octane, even if they don't.

Most modern cars, however, are designed to employ a specific compression ratio, a measure of how much room is available to the fuel when the piston is at the bottom and the top of the cylinder. This compression ratio—somewhere in the neighborhood of eight to one—tolerates lower octane fuels (such as regular gasoline, good old 87 octane) without knocking. "The compression ratio is fixed by the designer of the engine," Green says. "The regular fuel will burn properly and the premium fuel will burn properly and therefore there is no reason you should pay the extra money."

High-performance engines, such as those in some sports cars or older, heavier automobiles, often boast much higher compression ratios. These cars—for example, Shepherd's Subaru WRX—require premium gasoline and will definitely knock without it. "I have to put the 92 octane in," he says. "It has a turbocharger."

Such high compression ratios—and the premium fuels that go with them—could be turned to efficiency, rather than speed, Green notes, especially if put into the engines of lighter cars like his Honda Civic. Other automotive fuels, such as ethanol, can also offer high octane ratings, allowing oil companies to use more volatile gasoline in such blends. But for standard cars on the road today, purchasing premium gasoline is simply paying a premium for a fuel that delivers no added benefits. "If you think you need it," Green says, "you're being very eccentric."

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SECTION 5

Health Habits

Raw Veggies Are Healthier Than Cooked Ones

by Sushma Subramanian

Cooking is crucial to our diets. It helps us digest food without expending huge amounts of energy. It softens food, such as cellulose fiber and raw meat, that our small teeth, weak jaws and digestive systems aren't equipped to handle. And while we might hear from raw foodists that cooking kills vitamins and minerals in food (while also denaturing enzymes that aid digestion), it turns out raw vegetables are not always healthier.

A study published in *The British Journal of Nutrition* found that a group of 198 subjects who followed a strict raw food diet had normal levels of vitamin A and relatively high levels of beta-carotene (an antioxidant found in dark green and yellow fruits and vegetables), but low levels of the antioxidant lycopene.

Lycopene is a red pigment found predominantly in tomatoes and other rosy fruits such as watermelon, pink guava, red bell pepper and papaya. Several studies conducted in recent years (at Harvard Medical School, among others) have linked high intake of lycopene with a lower risk of cancer and heart attacks. Rui Hai Liu, an associate professor of food science at Cornell University who has researched lycopene, says that it may be an even more potent antioxidant than vitamin C.

One 2002 study he did (published in the *Journal of Agriculture and Food Chemistry*) found that cooking actually boosts the amount of lycopene in tomatoes. He tells *ScientificAmerican.com* that the level of one type of lycopene, cis-lycopene, in tomatoes rose 35 percent after he cooked them for 30 minutes at 190.4 degrees Fahrenheit (88 degrees Celsius). The reason, he says: the heat breaks down the plants' thick cell walls and aids the body's uptake of some nutrients that are bound to those cell walls.

Cooked carrots, spinach, mushrooms, asparagus, cabbage, peppers and many other vegetables also supply more antioxidants, such as carotenoids and ferulic acid, to the body than they do when raw, Liu says. At least, that is, if they're boiled or steamed. A January 2008 report in the *Journal of Agriculture and Food Chemistry* said that boiling and steaming better preserves antioxidants, particularly carotenoid, in carrots, zucchini and broccoli, than frying, though boiling was deemed the best. The researchers studied the impact of the various cooking techniques on compounds such as carotenoids, ascorbic acid and polyphenols.

Deep fried foods are notorious sources of free radicals, caused by oil being continuously oxidized when it is heated at high temperatures. These radicals, which are highly reactive because they have at least one unpaired electron, can injure cells in the body. The antioxidants in the oil and the vegetables get used up during frying in stabilizing the cycle of oxidation.

Another study published in the *Journal of Agricultural and Food Chemistry* in 2002 showed that cooking carrots increases their level of beta-carotene. Beta-carotene belongs to a group of antioxidant substances called carotenoids, which give fruits and vegetables their red, yellow, and orange colorings. The body converts beta-carotene into vitamin A, which plays an important role in vision, reproduction, bone growth and regulating the immune system.

The downside of cooking veggies, Liu says: it can destroy the vitamin C in them. He found that vitamin C levels declined by 10 percent in tomatoes cooked for two minutes—and 29 percent in tomatoes that were cooked for half an hour at 190.4 degrees F (88 degrees C). The reason is that Vitamin C, which is highly unstable, is easily degraded through oxidation, exposure to heat (it can increase the rate at which vitamin C reacts with oxygen in the air) and through cooking in water (it dissolves in water).

Liu notes, however, that the trade-off may be worth it since vitamin C is prevalent in far more fruits and vegetables than is lycopene. Among them: broccoli, oranges, cauliflower, kale and carrots. Besides, cooked vegetables retain some of their vitamin C content.

That said, research shows that some veggies, including broccoli, are healthier raw rather than cooked. According to a study in the *Journal of Agricultural and Food Chemistry* in November 2007, heat damages the enzyme myrosinase, which breaks down glucosinates (compounds derived from glucose and an amino acid) in broccoli into a compound known as sulforaphane.

Research published in the journal *Carcinogenesis* in December 2008 found that sulforaphane might block the proliferation of and kill precancerous cells. A 2002 study in *The Proceedings of the National Academy of Sciences* also found that sulforaphane may help fight the bacterium *Helicobacter pylori*, which causes ulcers and increases a person's risk of stomach cancer.

On the other hand, indole, an organic compound, is formed when certain plants, particularly cruciferous vegetables such as broccoli, cauliflower and cabbage, are cooked. According to research in *The Journal of Nutrition* in 2001, indole helps kill precancerous cells before they turn malignant. And while boiling carrots was found to increase carotenoid levels, another study found that it leads to a total loss of polyphenols, a group of chemicals found in raw carrots. Specific polyphenols have been shown to have antioxidant properties and to reduce the risk of cardiovascular disease and cancer, according to a 2005 report in *The American Journal of Clinical Nutrition*.

Comparing the healthfulness of raw and cooked food is complicated, and there are still many mysteries surrounding how the different molecules in plants interact with the human body. The bottom line, says Liu, is to eat your veggies and fruits no matter how they're prepared.

"We cook them so they taste better," Liu says. "If they taste better, we're more likely to eat them." And that's the whole idea.

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Greasy Foods Equal Bad Skin

by Cynthia Graber

A teenage boy scarfs down an entire bucket of fried chicken. The next morning he wakes up with red bumps roiling over his skin. Is there a connection? Did eating all that greasy food give him a bad case of the zits? The simple answer for the past 30 years has been a resolute no. But today, new research suggests the answer is more complicated: maybe.

The fat you put in your mouth does not reappear on your skin. When you eat, the food goes through the digestive system, which breaks down that fried chicken into nutrients that can be easily absorbed and utilized. Bile acids dissolve fat in water in the intestinal cavity. Enzymes break the larger fat molecules into smaller ones. Cell walls absorb these molecules, which are then transported to the veins in the chest and fat storage areas around the body.

Pimples have no connection to these fat deposits. Acne forms because the ducts that connect the sebaceous glands in the skin, which dispense oil to keep skin soft and healthy, are overactive and produce an excess of oil and cells. These build up in the duct and clog pores with a firm, oil-soaked plug. Bacteria and yeast thrive in this environment. The body's immune system responds, inflaming the area and turning it embarrassingly red.

Testosterone is the antagonist in the acne story, because it dials up the activity of both the sebaceous glands and the lining cells. When girls go through what's known as menarche, or puberty, the surge of hormones in their bodies includes testosterone. For boys, the testosterone concentration is obviously higher; that is why teen boys tend to have worse acne, which is spread more generally over their bodies. Acne usually dissipates when these hormone surges calm down (and, along with them, the teenagers in question). Acne persists in some individuals, either when women menstruate—a hormonal change—or because certain people have a genetic predisposition to acne.

Diet, it turns out, influences these hormones. Dermatologist William Danby collected extensive dietary information on his patients from 1973 to 1980 as part of an interest in potential food links to pimple outbreaks. "It became obvious over the years that dairy consumers had greater acne," Danby says. He also found a paper published as far back as 1966 that tied acne to dairy consumption based on interviews with 1,000 patients.

Danby advises all those afflicted with the red bumps to swear off milk products for six months. The results, he says, support the link. One man, the 61-year-old son of an ice cream maker with horrible lifelong acne (and a lifelong addiction to ice cream), finally gave up dairy, and "in a year he was clear of all fresh lesions," Danby says.

Danby also worked with researchers at the Harvard School of Public Health on a retrospective epidemiological study of more than 47,000 nurses, published in the *Journal of the American Academy of Dermatology* (*JAAD*) in 2005, along with another on their daughters that found a significant connection between increased dairy and acne. Another study on the nurses' sons is awaiting publication. Though the method of action has not yet been confirmed, Danby notes that milk from pregnant cows contains hormones that oil glands can turn into dihydrotestosterone, testosterone's

most potent form.

An Australian article also in *JAAD*, demonstrates that high-glycemic diets, rife with white flour and processed carbohydrates, appear to lead to higher acne, although the authors say further research is needed to replicate the results. They believe the method of action may be linked to resulting insulin spikes, already associated with increased levels of male hormones in both sexes.

Dermatologist Valori Treloar, co-author of *The Clear Skin Diet*, believes the types of fats we eat affect acne. So-called "bad" fats, frequently disparaged for a variety of ills, have been linked in heart studies to increased inflammation—the culprit behind the bright red bumps. Good fats, omega-3 fatty acids, are known for anti-inflammatory properties. Treloar also points to dietary and health studies showing that populations that consume traditional diets high in good fats and low in bad fats have significantly lower incidences of acne. This specific food connection, however, has not been confirmed in controlled studies.

Many dermatologists still say that there's no known link between food and acne, but usually add that if a patient notices a trigger, food or otherwise, they should avoid it. This is slowly changing: According to dermatologist Wendy Roberts, "the younger generation [of dermatologists] says, 'sure, we see people who have a dietary response… But we can't say what's causing it.'"

So did fried chicken trigger the boy's breakout? Not directly—unless he smeared it on his face. But new studies present intriguing hints that his food may have played an indirect role.

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Water, Part 1: You Must Drink 8 Glasses of Water Daily

by Karen Bellenir

Virtually every health-conscious person can quote the recommendation: Drink at least eight eight-ounce glasses of water per day. Other beverages—coffee, tea, soda, beer, even orange juice—don't count. Watermelon? Not a chance.

There's no denying that water is good for you, but does everyone really need to drink 64 ounces or more every day? According to Heinz Valtin, a retired professor of physiology from Dartmouth Medical School who specialized in kidney research and spent 45 years studying the biological system that keeps the water in our bodies in balance, the answer is no.

Valtin says that for people who have specific health concerns, such as kidney stones or a tendency to develop urinary tract infections, drinking lots of water can be beneficial. But after an extensive search in 2002 for the origins of what is commonly referred to as the "8 x 8" guideline and a review of associated health claims, he reports finding no scientific evidence supporting the notion that healthy individuals need to consume large quantities of water. In 2008 Dan Negoianu and Stanley Goldfarb reviewed the evidence for the *Journal of the American Society of Nephrology*. They came to a similar conclusion: "There is no clear evidence of benefit from drinking increased amounts of water."

In fact, Valtin found that the 8 x 8 guideline may have originated from a misunderstanding. In 1945 the Food and Nutrition Board, now part of the National Academy of Sciences's Institute of Medicine, suggested that a person consume one milliliter of water (about one fifth of a teaspoon) for each calorie of food. The math is pretty simple: A daily diet of around 1,900 calories would dictate the consumption of 1,900 milliliters of water, an amount remarkably close to 64 ounces. But many dieticians and other people failed to notice a critical point: namely, that much of the daily need for water could be met by the water content found in food.

The Board revisited the question of water consumption in 2004. Its panel on "dietary preference intakes for electrolytes and water" noted that women who appear adequately hydrated consume about 91 ounces (2.7 liters) of water a day and men about 125 ounces (3.7 liters). These seemingly large quantities come from a variety of sources—including coffee, tea, milk, soda, juice, fruits, vegetables and other foods. Instead of recommending how much extra water a person should drink to maintain health, the panel simply concluded that "the vast majority of healthy people adequately meet their daily hydration needs by letting thirst be their guide."

Advocates of the 8 x 8 guideline sometimes claim that thirst is a poor hydration indicator. They assert that many people are so chronically dehydrated they no longer recognize their bodies' signals for water. Barbara Rolls, professor of nutrition sciences at the Pennsylvania State University, disagrees. Her studies, she says, "found no evidence that people are chronically dehydrated." Although some drugs can cause problems with thirst regulation and the elderly may not experience thirst as intensely as younger people, Rolls maintains that most healthy people are adequately hydrated.

Weight loss is another benefit often touted by proponents of the 8 x 8 guideline. They claim people mistake thirst for hunger, which causes them to eat when they are really just thirsty. They also allege that drinking water suppresses appetite. Given the obesity crisis, every little bit (or drop) helps.

But Rolls disagrees, arguing that "drinking water and waiting for pounds to melt away does not work. We all wish it were that simple." She explains that "hunger and thirst are controlled by separate systems in the body. People are unlikely to mistake thirst for hunger." Furthermore, she reports that her studies "never found that drinking water with or before a meal affected appetite." Nevertheless, there are some elements of truth in the misperception. Rolls did find that water-rich foods—as opposed to stand-alone water—tended to help people consume fewer calories. And, she says, "there is a way that water can help with weight loss—if you use water as a substitute for a caloric beverage."

Neither Rolls nor Valtin opposes the idea of including water in a healthy diet. They both note that the body needs water to function properly and that dehydration hurts the body. They do object, however, to the notion that a universally true guideline governs ideal water consumption. "Water requirements depend so much on outside temperature, activity levels and other factors that there isn't one rule that fits everybody," Rolls says. And Valtin cautions that in some situations drinking too much water can actually be dangerous, even fatal.

So how much water should you drink? Here's their advice: If you have specific medical concerns, talk to your doctor. But if you are healthy, Rolls recommends that you "have a beverage with meals and drink when you are thirsty." In other words, heed your thirst signals, enjoy that watermelon, and stop feeling guilty for not guzzling those extra glasses.

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Water, Part 2: Too Much Can Kill You

by Coco Ballantyne

Liquid H_2O is the sine qua non of life. Making up about 66 percent of the human body, water runs through the blood, inhabits the cells, and lurks in the spaces between. At every moment water escapes the body through sweat, urination, defecation or exhaled breath, among other routes. Replacing these lost stores is essential but rehydration can be overdone. There is such a thing as a fatal water overdose.

In 2007, a 28-year-old California woman died after competing in a radio station's on-air water-drinking contest. After downing some six liters of water in three hours in the "Hold Your Wee for a Wii" (Nintendo game console) contest, Jennifer Strange vomited, went home with a splitting headache, and died from so-called water intoxication.

There are many other tragic examples of death by water. In 2005 a fraternity hazing at California State University, Chico, left a 21-year-old man dead after he was forced to drink excessive amounts of water between rounds of push-ups in a cold basement. Club-goers taking MDMA ("ecstasy") have died after consuming copious amounts of water trying to rehydrate following long nights of dancing and sweating. Going overboard in attempts to rehydrate is also common among endurance athletes. A 2005 study in the *New England Journal of Medicine* found that close to one sixth of marathon runners develop some degree of *hyponatremia*, or dilution of the blood caused by drinking too much water.

Hyponatremia, a word cobbled together from Latin and Greek roots, translates as "insufficient salt in the blood." Quantitatively speaking, it means having a blood sodium concentration below 135 millimoles per liter, or approximately 0.4 ounces per gallon, the normal concentration lying somewhere between 135 and 145 millimoles per liter. Severe cases of hyponatremia can lead to water intoxication, an illness whose symptoms include headache, fatigue, nausea, vomiting, frequent urination and mental disorientation.

In humans the kidneys control the amount of water, salts and other solutes leaving the body by sieving blood through their millions of twisted tubules. When a person drinks too much water in a short period of time, the kidneys cannot flush it out fast enough and the blood becomes waterlogged. Drawn to regions where the concentration of salt and other dissolved substances is higher, excess water leaves the blood and ultimately enters the cells, which swell like balloons to accommodate it.

Most cells have room to stretch because they are embedded in flexible tissues such as fat and muscle, but this is not the case for neurons. Brain cells are tightly packaged inside a rigid boney cage, the skull, and they have to share this space with blood and cerebrospinal fluid, explains Wolfgang Liedtke, a clinical neuroscientist at Duke University Medical Center. "Inside the skull there is almost zero room to expand and swell," he says.

Thus, brain edema, or swelling, can be disastrous. "Rapid and severe hyponatremia causes entry of water into brain cells leading to brain swelling, which manifests as seizures, coma, respiratory arrest, brain stem herniation and death," explains M. Amin Arnaout, chief of nephrology at Massachusetts General Hospital and Harvard Medical School.

Where did people get the idea that guzzling enormous quantities of water is healthful? A few years ago Heinz Valtin, a kidney specialist from Dartmouth Medical School, decided to determine if the common advice to drink eight, eight-ounce glasses of water per day could hold up to scientific scrutiny. After scouring the peer-reviewed literature, Valtin concluded that no scientific studies support the "eight x eight" dictum (for healthy adults living in temperate climates and doing mild exercise). In fact, drinking this much or more "could be harmful, both in precipitating potentially dangerous hyponatremia and exposure to pollutants, and also in making many people feel guilty for not drinking enough," he wrote in his 2002 review for the *American Journal of Physiology—Regulatory, Integrative and Comparative Physiology*. And since he published his findings, Valtin says, "not a single scientific report published in a peer-reviewed publication has proven the contrary."

Most cases of water poisoning do not result from simply drinking too much water, says Joseph Verbalis, chairman of medicine at Georgetown University Medical Center. It is usually a combination of excessive fluid intake and increased secretion of vasopression (also called antidiuretic hormone), he explains. Produced by the hypothalamus and secreted into the bloodstream by the posterior pituitary gland, vasopressin instructs the kidneys to conserve water. Its secretion increases in periods of physical stress—during a marathon, for example—and may cause the body to conserve water even if a person is drinking excessive quantities.

Every hour, a healthy kidney at rest can excrete 800 to 1,000 milliliters, or 0.21 to 0.26 gallon, of water and therefore a person can drink water at a rate of 800 to 1,000 milliliters per hour without experiencing a net gain in water, Verbalis explains. If that same person is running a marathon, however, the stress of the situation will increase vasopressin levels, reducing the kidney's excretion capacity to as low as 100 milliliters per hour. Drinking 800 to 1,000 milliliters of water per hour under these conditions can potentially lead a net gain in water, even with considerable sweating, he says.

While exercising, "you should balance what you're drinking with what you're sweating," and that includes sports drinks, which can also cause hyponatremia when consumed in excess, Verbalis advises. "If you're sweating 500 milliliters per hour, that is what you should be drinking."

But measuring sweat output is not easy. How can a marathon runner, or any person, determine how much water to consume? As long as you are healthy and equipped with a thirst barometer unimpaired by old age or mind-altering drugs, follow Verbalis's advice, "drink to your thirst. It's the best indicator."

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Antioxidant Supplements Help You Live Longer

by Jonathan Scheff
with reporting by Willa Austen Isikoff

If antioxidant supplement labels are to be believed, you should stop reading this article and gobble down some pills: Spurred by the rising sales of antioxidant supplements, Pom Wonderful, makers of pomegranate juice, now makes an antioxidant supplement that they claim has "extraordinary health benefits."

This proclamation is echoed by numerous health supplement ads in health food stores and on the Internet. For instance, Source Naturals Resveratrol advises on the General Nutrition Centers Web site that taking antioxidants"…may help prevent free-radical damage throughout the body and provide protective support to the cardiovascular system." Problem solved. Except a bit of a buzz-kill is delivered by the asterisked footnote: *"These statements have not been evaluated by the Food and Drug Administration. This product is not intended to diagnose, treat, cure or prevent any disease."*

So, do the purported health benefits of antioxidants actually exist?

Here's the theory: Just as the name suggests, antioxidants slow down oxidation, a process that is part of normal bodily functions but can also damage cells. Oxidation can even increase the stickiness of cholesterol, upping the risk that it will block circulation and cause heart attacks or strokes.

So it at least theoretically makes sense that antioxidants such as vitamin C, vitamin E and other antioxidant compounds found in carrots and other vegetables, are good for you. Ditto antioxidants found in pomegranates, red wine and licorice root. And early studies in the 1990s showed that people who ate more antioxidants had a lower risk of heart disease and stroke.

But those findings didn't hold up for antioxidant supplements. In later studies, such supplements did not affect risk of—and in some studies actually increased—heart attacks and strokes.

Nancy Cook, an epidemiologist at Brigham and Women's Hospital in Boston and a co-author of one of these studies, suggests two possible explanations for these results: It could be that studies of supplements are using the wrong doses and combinations of antioxidants. Or, people who eat lots of antioxidants—in foods, not supplements—are already doing the kinds of things that lower heart disease risk, namely exercise and, well, eating plenty of fruits and vegetables.

Biochemist Michael Aviram of the Rambam Medical Center in Haifa, Israel, suggests another alternative. His research focuses on pomegranates. In a recent study, he found that mice bred to have blockages in their arteries and developed fewer blockages in their arteries after they were fed parts of pomegranates. Because such blockages can cause heart attacks and strokes, he says his studies suggest antioxidants work against such events. And although earlier studies found that vitamin E—another antioxidant—didn't clear such blockages, he found that the kinds of antioxidants in pomegranates do. His theory: there are many sources of oxidative stress—viruses, toxins, physical strain—and each antioxidant might be effective against a particular type of stress, but not the others.

In other words, it depends whether the antioxidants you're taking are fighting against the good,

normal oxidation in your body or the bad oxidation. "The devil's in the details in a lot of these things," says Andrew Shao of the Council for Responsi]

Vitamin Supplements Improve Your Health

by Coco Ballantyne

Vita means "life" in Latin, and vitamins are essential for life. The World Health Organization calls them the "magic wands" used by the body to synthesize enzymes, hormones and other chemical necessities. Unable to create vitamins from scratch, the body must fetch them from outside sources—typically food. But do the pills many pop for health deliver the same benefits?

Humans need 13 vitamins to survive. Vitamins, also called "micronutrients" because they are required in minute quantities, can be grouped in two categories. There are those that dissolve in fat—A, D, E and K—and can accumulate in the body when consumed in excess. And there are those that are water soluble—C and B—which are easily excreted, as anyone who takes large quantities of vitamin C and riboflavin (B_2) can testify. (Their urine is bright yellow or orange.)

The best way to get vitamins is through food, not vitamin pills, according to Susan Taylor Mayne, a professor at the Yale School of Public Health's Division of Chronic Disease Epidemiology. A major problem with supplements is that they deliver vitamins out of context, she says. The vitamins found in fruit, vegetables and other foods come with thousands of other phytochemicals, or plant nutrients that are not essential for life but may protect against cancer, cardiovascular disease, Alzheimer's disease and other chronic ailments. Carotenoids in carrots and tomatoes, isothiocyanates in broccoli and cabbage, and flavonoids in soy, cocoa and red wine are just a few examples.

The combined effect of all these vitamins and phytochemicals seems to have much greater power than one nutrient taken alone, Mayne explains. For example, lycopene—the carotenoid that gives tomatoes their red hue—has been associated with a lower risk for prostate cancer, causing many supplement makers to rush to market pills bearing this healthy stuff. But research suggests that taking it in supplement form does not confer the same benefit as eating tomatoes or tomato products, such as pasta sauce and ketchup, that preserve some of the tomato!s chemical integrity.

A healthy diet is paramount, but is there ever a time for supplements? Meir Stampfer, professor of nutrition and epidemiology at the Harvard School of Public Health in Boston, recommends that healthy adults take a multivitamin and extra vitamin D, if they don't get a lot of sun. Taking more than the Institute of Medicine's recommended daily allowance (RDA) of certain vitamins may lower one's risk for certain chronic diseases, he says. For example, Stampfer's research suggests that men and women taking vitamin E supplements for years at a time have a lower risk for heart disease. "The evidence for benefit is weak," but there is also "good evidence for no harm" associated with taking 200, 400, or even 600 IUs (international units) per day, Stampfer explains. (The RDA levels for vitamin E are 22.5 IUs, or 15 milligrams, for men and women.)

Mayne disagrees, pointing to a recent meta-analysis suggesting that vitamin E supplementation increases mortality of all causes. "We can debate" whether this analysis shows that vitamin E supplements are harmful, she says, but "there certainly wasn't any benefit shown." With the possible exception of vitamin D, there is no need to consume more than the RDA of vitamins, Mayne contends. In fact, there is increasing evidence that excessive intake of certain micronutrients is deleterious.

Stampfer acknowledges that overdosing on certain vitamins can be dangerous. "The most common one to look out for is preformed [active form] … vitamin A. It does not take too much to get too much," he says. Try to avoid retinol, retinyl palmitate and retinyl acetate, which may increase the risk of hip fracture and certain birth defects when taken at levels exceeding 10,000 IUs.

But Mayne and Stampfer both agree that more randomized clinical trials are needed to determine the health effects of vitamin supplements—and that such supplements are critical for certain people. Many African-Americans and people living in sun-deprived areas are vitamin D–deficient and could benefit from supplements, Mayne explains. Pregnant women, and even women who might want to get pregnant, should be taking folic acid supplements to help prevent serious birth defects in their babies. People over 50 years of age can benefit from B_{12} supplementation because absorption of this vitamin in the digestive tract becomes less efficient with age, says Roberta Anding, spokeswoman for the American Dietetic Association. Finally, HIV-positive patients should take multivitamins to boost immunity and slow the rate of disease progression, says Wafaie Fawzi, professor of nutrition and epidemiology at the Harvard School of Public Health.

Ironically, "the people who are most likely to take vitamin supplements are the people who least need them," Mayne says. The affluent and health conscious are popping supplements faster than anyone. It may not be doing any good, and it could be harming them, she says. Anding concurs: "If you eat well, you probably don't need a multivitamin."

On the other hand, as Stampfer, who takes vitamin supplement himself, notes: "If I'm wrong, then I've wasted a few dollars. If I'm right, I've lowered my risk for some diseases I don't want to have."

--Originally published: Scientific American Online May 17, 2007.

Generic Drugs Are Bad for You

by Molly Webster

As we cope with the economic recession, we've all had to make concessions. It's been "good-bye" to European vacations, organic milk and magazine subscriptions. But there are those things we can't give up without risking serious illness or death, one of which is prescription medication.

In 2004 the U.S. Centers for Disease Control estimated that at least 47 percent of Americans had a prescription filled each month. Besides ordering brand-name pills, powders and sprays from Canada, some people are trying to cut costs by turning to generic medications. But don't worry: unlike switching from a real Louis Vuitton purse to a knockoff bought in Chinatown, this isn't a switch that will leave you aching for the real thing in a few months time.

"In theory, generics are every bit as high quality as brand name," says William Hubbard, a former associate commissioner of the U.S. Food and Drug Administration (FDA). "I would readily take a generic if it was prescribed to me."

A generic drug contains the same active ingredient, which provides therapeutic benefit, as does the brand-name version. But having the same medicinal component does not mean the two pharmaceuticals are identical. They may contain different inactive ingredients, including those for pill coatings and color or to bind the constituents into tablet form. They also may vary in bioequivalency, which is the amount of drug that is available in the bloodstream at any point in time. In fact, a 2009 FDA study showed that of 2,070 orally administered generic drug products approved by the agency between 1996 to 2007, generics differ in bioequivalency from brand names, on average, by about 3.5 percent; less than two percent varied by more than 10 percent. For many, these differences are not significant enough to reduce therapeutic benefits or, on the other hand, cause toxicity.

"For the vast majority of patients, switching is not an issue," says Aaron Kesselheim, a physician and drug policy researcher at Harvard's Brigham and Women's Hospital. Kesselheim is author of a 2008 study that showed there are no statistically significant therapeutic differences among generic and brand-name heart medications.

The minority of patients for whom a switch might be problematic are those on narrow-margin therapeutic index drugs, such as anticoagulants and antihypertension meds for which there is a fine line between a dosage that is beneficial and one that is toxic. Even when using pioneer (or brand-name) drugs, doctors monitor patients on these types of medications until they find the precise dose that works with each person's physiology. Switching medication, especially if there's even a small bioequivalence variability, can introduce a change that throws off therapy.

"If a person is stable on narrow therapeutic index drug, it makes sense to think two times about changing to a generic or to a new brand-name drug," Kesselheim says.

Despite convincing scientific evidence that generic drugs are largely equivalent to pioneer meds, there remains an undercurrent of fear toward nonbrand names. In fact, as part of Kesselheim's 2008 study in *JAMA The Journal of the American Medical Association*, his team reviewed 43 editorials that had been published in peer-review health care journals between 1975 and 2008 concerning

generic substitutions for branded cardiovascular disease pharmaceuticals. The study found that 53 percent expressed a negative view toward generics. There's myriad sources that could explain the worry, including patient case reports and antigeneric advertising by brand name drug companies. But to be fair, much of the concern is rooted in some scary generic drug scandals, in which toxic substances made it into a medication that was produced overseas, such as occurred with heparin in 2008. Today, more than 40 percent of the active ingredients in generic and over-the-counter pharmaceuticals are produced in India and China—and that number is only expected to increase: In the next few years a number of brand-name pharmaceuticals will be going off patent, with the expectation that within 10 years, 80 percent of the prescriptions Americans take will be generic.

And, although generics have thus far been shown to be as effective and safe as branded drugs, there is a concern that they are more likely than brand-name meds to be the target of adulteration with toxic substances, because some companies might be tempted to cut corners in efforts to keep them as cheap as possible.

"FDA requirements are pretty strict," Hubbard says, "but foreign firms don't have the same culture of safety and oversight—and they are interested in the lowest price."

According to the FDA, the rules that it has set to regulate generic drugs are just as tough as for brand-name meds. But keep in mind that the federal agency was originally formed as a domestic watchdog—overseas expansion and the proliferation of pharmaceutical manufacturers have challenged their infrastructure. *The New York Times* reported that in 2007, out of 500 Chinese facilities the FDA only got around to checking 13. Acknowledging this situation, the agency is looking to expand overseas staff in an attempt to ramp up on-the-ground regulation of manufacturing facilities. In 2008 the FDA opened three offices in China and two in India, not to mention others in Costa Rica and Belgium. Hubbard further suggests that in the future, all foreign facilities with any role in the U.S. pharmaceutical industry should be required to register with the FDA, providing contact information as well as a list of their product lines.

Plus, the U.S. Pharmacopeia (USP), a standard-setting authority for prescription and over-the-counter meds, has recently changed some of the identification tests that manufacturers are required to run on products destined for the U.S. These newer, more stringent analyses are more sensitive to impurities than prior protocols were. (And, for what it's worth, the USP is also trying to organize momentum for establishing some tougher food tests—think: melamine.)

Today, however, Hubbard says that prescription-takers "don't need to panic": 67 percent of Americans take generic medication, and there are few adverse instances to recount. And studies have shown them to be just as effective as branded meds.

So, with the great recession raging, bring on the generics.

--Originally published: Scientific American Online November 12, 2009.

Antiperspirants Do More Than Block Sweat

by S. M. Kramer

For some, the thought of abandoning antiperspirants gives them the cold sweats. For others, it's the thought of using them. Underarm antiperspirants guard against odor and wetness, but could the aluminum-based compounds that reduce sweat actually cause Alzheimer's disease and breast cancer?

The antiperspirant finger-pointing began more than 40 years ago with new discoveries about Alzheimer's, a progressive dementia that affects more than five million Americans. Antiperspirants use compounds—such as aluminum chloride, aluminum chlorohydrate and aluminum zirconium—to form a temporary sweat duct plug. Researchers back then found that exposure to aluminum caused rabbits' brains to develop nerve cell damage—thought to be a precursor to Alzheimer's at the time—and long-term dialysis patients with high levels of the metal developed dementia.

Critics charge that rabbits are not good animal models for human brain diseases and note that the dialysis patients suffered from dialysis encephalopathy, or "dialysis dementia," not Alzheimer's disease. But neuropathologist Daniel P. Perl at Mount Sinai Medical Center in New York City has found evidence of aluminum in the neurofibrillary tangles that characterize Alzheimer's disease.

"Just because the rabbit is not a good model doesn't mean that there is not a problem," he says. "There are a zillion examples of things that are clearly toxic to humans, but when exposed to rats—even monkeys—show no problem."

On average, most people take in approximately 30 to 50 milligrams per day of aluminum from food; those using over-the-counter medications such as antacids and buffered aspirins ingest larger amounts, roughly five grams a day. At that level, there is little evidence of harm, most experts say.

Skeptics cite such a lack of epidemiologic evidence in the decades since the concern was first raised and say avoiding the third most common element in Earth's crust is impossible. Even if people were to ban aluminum pots and pans, chuck soda cans or cap antiperspirants, the ubiquitous metal would still be in the food they eat, the water they drink and, sometimes, even in the air they breathe.

"Everyone's been exposed, which makes it very difficult to study," says epidemiologist Amy Borenstein of the College of Public Health at the University of South Florida in Tampa. Her 1990 case-control study, reported in the *Journal of Clinical Epidemiology*, found no association between aluminum-containing products and Alzheimer's disease. "If it even plays a role at all," she says, "it's negligible."

William Thies, vice president of medical and scientific relations at the Alzheimer's Association in Chicago, calls the notion that antiperspirants could cause Alzheimer's disease an old legend. "One of the things that happens in Alzheimer's brains is that they shrink," he says. "So, you have accumulated a certain amount of aluminum in your brain, and as your brain shrinks, the concentration is going to appear high."

Cancer has also been a source of concern for some, which may have originated with instructions that women avoid antiperspirants, deodorants, powders and lotions before mammograms in order to

avoid confusing shadows on X-rays. This may have led to confusion about a potential link between cancer and personal care products.

Adding to uncertainty, in the 1990s an anonymous e-mail chain letter warned that antiperspirants caused breast cancer. Ted Gansler, director of medical content at the American Cancer Society in Atlanta, says that in the past seven years, his organization has received thousands of e-mails and phone calls in response to this chain letter.

The letter claims that inhibiting perspiration causes harmful substances to be trapped in the body where they form cancer. But sweat is mostly electrolytes and water, Gansler says, and sweating is not a significant mechanism for expelling unwanted compounds, more commonly eliminated in urine and feces. "It would be nice if as many people as [those who] forwarded the e-mail about antiperspirants, urged their friends and relatives to get a mammogram every year starting at age 40," he says. "We would have saved a lot more lives."

The idea that toxics would enter the body through the underarm, migrate to the lymph nodes and then travel to the breast may have more to do with geography than biology. "Why you would think that antiperspirant would somehow go upstream and get into your lymph nodes and then somehow get into the breast is unclear," says Timothy Moynihan, education chair and consultant for the division of medical oncology at the Mayo Clinic in Rochester, Minn. "It doesn't make sense other than the fact that it's in the neighborhood."

Ultimately, lifestyle changes like exercising are more important than whether or not your underarms are sweaty while you are walking around or working out. "Everyone worries about underarm antiperspirants," Moynihan adds, "but nobody quits smoking."

--Originally published: Scientific American Online August 9, 2007.

Antibacterial Products May Do More Harm Than Good

by Coco Ballantyne

Tuberculosis, food poisoning, cholera, pneumonia, strep throat and meningitis: these are just a few of the unsavory diseases caused by bacteria. Hygiene—keeping both home and body clean—is one of the best ways to curb the spread of bacterial infections, but lately consumers are getting the message that washing with regular soap is insufficient. Antibacterial products have never been so popular. Body soaps, household cleaners, sponges, even mattresses and lip glosses are now packing bacteria-killing ingredients, and scientists question what place, if any, these chemicals have in the daily routines of healthy people.

Traditionally, people washed bacteria from their bodies and homes using soap and hot water, alcohol, chlorine bleach or hydrogen peroxide. These substances act nonspecifically, meaning they wipe out almost every type of microbe in sight—fungi, bacteria and some viruses—rather than singling out a particular variety.

Soap works by loosening and lifting dirt, oil and microbes from surfaces so they can be easily rinsed away with water, whereas general cleaners such as alcohol inflict sweeping damage to cells by demolishing key structures, then evaporate. "They do their job and are quickly dissipated into the environment," explains microbiologist Stuart Levy of Tufts University School of Medicine.

Unlike these traditional cleaners, antibacterial products leave surface residues, creating conditions that may foster the development of resistant bacteria, Levy notes. For example, after spraying and wiping an antibacterial cleaner over a kitchen counter, active chemicals linger behind and continue to kill bacteria, but not necessarily all of them.

When a bacterial population is placed under a stressor—such as an antibacterial chemical—a small subpopulation armed with special defense mechanisms can develop. These lineages survive and reproduce as their weaker relatives perish. "What doesn't kill you makes you stronger" is the governing maxim here, as antibacterial chemicals select for bacteria that endure their presence.

As bacteria develop a tolerance for these compounds there is potential for also developing a tolerance for certain antibiotics. This phenomenon, called cross-resistance, has already been demonstrated in several laboratory studies using triclosan, one of the most common chemicals found in antibacterial hand cleaners, dishwashing liquids and other wash products. "Triclosan has a specific inhibitory target in bacteria similar to some antibiotics," says epidemiologist Allison Aiello at the University of Michigan School of Public Health.

When bacteria are exposed to triclosan for long periods of time, genetic mutations can arise. Some of these mutations endow the bacteria with resistance to isoniazid, an antibiotic used for treating tuberculosis, whereas other microbes can supercharge their efflux pumps—protein machines in the cell membrane that can spit out several types of antibiotics, Aiello explains. These effects have been demonstrated only in the laboratory, not in households and other real world environments, but Aiello believes that the few household studies may not have been long enough. "It's very possible that the emergence of resistant species takes quite some time to occur…; the potential is there," she says.

Apart from the potential emergence of drug-resistant bacteria in communities, scientists have other concerns about antibacterial compounds. Both triclosan and its close chemical relative triclocarban (also widely used as an antibacterial), are present in 60 percent of America's streams and rivers, says environmental scientist Rolf Halden, co-founder of the Center for Water and Health at Johns Hopkins Bloomberg School of Public Health. Both chemicals are efficiently removed from wastewater in treatment plants but end up getting sequestered in the municipal sludge, which is used as fertilizer for crops, thereby opening a potential pathway for contamination of the food we eat, Halden explains. "We have to realize that the concentrations in agricultural soil are very high," and this, "along with the presence of pathogens from sewage, could be a recipe for breeding antimicrobial resistance" in the environment, he says.

Triclosan has also been found in human breast milk, although not in concentrations considered dangerous to babies, as well as in human blood plasma. There is no evidence showing that current concentrations of triclosan in the human body are harmful, but recent studies suggest that it acts as an endocrine disrupter in bullfrogs and rats.

Further, an expert panel convened by the Food and Drug Administration determined that there is insufficient evidence for a benefit from consumer products containing antibacterial additives over similar ones not containing them.

"What is this stuff doing in households when we have soaps?" asks molecular biologist John Gustafson of New Mexico State University in Las Cruces. These substances really belong in hospitals and clinics, not in the homes of healthy people, Gustafson says.

Of course, antibacterial products do have their place. Millions of Americans suffer from weakened immune systems, including pregnant women and people with immunodeficiency diseases, points out Eugene Cole, an infectious disease specialist at Brigham Young University. For these people, targeted use of antibacterial products, such as triclosan, may be appropriate in the home, he says.

In general, however, good, long-term hygiene means using regular soaps rather than new, antibacterial ones, experts say. "The main way to keep from getting sick," Gustafson says, "is to wash your hands three times a day and don't touch mucous membranes."

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SECTION 6

The Body

Urinating on a Jellyfish Sting Will Ease the Pain

by Ciara Curtin

Back in 1997 all the friends from that eponymous television show trekked to the beach, only to witness a jellyfish sting Monica. In this episode, Joey remembered seeing a documentary that advised urinating on the sting to ease the pain. Monica agreed to try the treatment and it worked. Unfortunately, in the real world treating a jellyfish sting by urinating on it may actually cause someone in Monica's situation even more pain, rather than relief. Urine can actually aggravate the jellyfish's stingers into releasing more venom. This cure is, indeed, fiction.

Jellyfish, those bulbous Medusa-like creatures, float near many of the world's beaches. Some of the jellyfish's skin cells are stinging cells, or cnidocytes. These specialized cells have organelles called nematocysts that contain venom. Cnidocytes are spread along the entire length of the jellyfish's tentacles.

These tentacles can be so long that swimmers might not see the jellyfish that stings them, but they will certainly feel it. "The pain is instant," says Joseph Burnett, a dermatologist at the University of Maryland Medical Center, who is part of the school's Consortium of Jellyfish Stings, which tracks jellyfish injuries worldwide. Once stung, angry, red, whiplike lash marks mar the skin. The pain radiates from the sting site and starts to itch, burn and throb as it blisters. Scratching it, though, can make the pain worse, because rubbing activates the nematocysts, which release more venom.

Jellyfish stings are painful, but they are rarely life-threatening. For most such injuries, in North America at least, the pain will not last longer than 24 hours, typically peaking five minutes after the sting occurs then dissipating over the next few hours. "[But] it depends on what jellyfish gets you," notes Christopher Holstege, a toxicologist and professor of emergency medicine at the University of Virginia.

Those 24 hours, though, could be uncomfortable without any treatment, which can be administered on the beach. Both Burnett and Holstege recommend washing the area with saltwater. Such rinsing will deactivate those pesky nematocysts that are still hanging on.

A freshwater rinse will have the opposite effect. Any change to the balance of solutes, such as the concentration of salts inside and outside of the cnidocyte, sets off stinging. Adding freshwater to the sting site dilutes the salts outside the cell, unbalancing the solutes. In reaction to this change, the nematocysts in the cells release more venom--and cause more pain.

But what about urine? It contains salts and electrolytes. "I can think of many other things I'd rather have on me," Holstege notes. The concentration of salts and other compounds people have in their urine changes, he explains. If it is too dilute it will be similar to freshwater and cause those stingers to fire.

Other liquids and compounds, however, can help. Most stings in North American waters can be assuaged by vinegar, or 5 percent acetic acid. For stings from a few species, *Cyanea capillata* and *Chysaora quinquecirrha*, a baking soda and seawater paste is even better.

Once rinsing deactivates all the nasty nematocysts, the attached bits of tentacle can be removed by coating them with shaving cream or a slurry of seawater and sand followed by shaving with a razor or even a credit card.

For pain, an oral analgesic should do the trick for North American jellyfish stings. Australia, though, has nastier jellyfish (such as the deadly Box Jellyfish) and most Australian lifeguard teams are equipped with morphine and antivenoms to treat unlucky swimmers Down Under.

Ultimately, time, not urine, is the best treatment for a jellyfish sting. "Urine is worthless," Burnett says.

--Originally published: Scientific American Online January 4, 2007.

It's No Tall Tale, Height Matters

by Fran Hawthorne

Short people know the sad litany all too well: Numerous studies show that they probably earn less than taller colleagues. They get fewer dates as well as fewer promotions. Their bosses are probably taller than they are—in fact, more than half of U.S. CEOs clock reach six-feet- (183-centimeters-) plus. And if all that wasn't depressing enough, now comes word from Johns Hopkins University that height-advantaged Americans—particularly women—are also less likely to suffer from dementia.

So, as the song goes, do short people really have no reason to live, or is that a tall tale?

Height does not seem to be a prerequisite for greatness. Both Napoleon Bonaparte and Ludwig van Beethoven didn't make it to 67 inches (170 centimeters) tall. Mahatma Gandhi was even shorter. And the list of accomplished actors, musicians and other creative types who are short—defined as 57 inches (145 centimeters) for an 18-year-old boy and 56 inches (142 centimeters) for his female counterpart—is long.

But, as the Johns Hopkins study indicates, these sad short stories aren't just urban myths. Many are backed up by scientific research. Usually, the explanation goes back to childhood nutrition, especially during the first two years of life, says Tina Huang, the study's lead author, a researcher at Tufts University's Jean Mayer USDA Human Nutrition Research Center on Aging. Starved of adequate food, neither brain nor body develops appropriately.

Huang's study, published in *Neurology*, analyzed cognitive data, floor-to-knee measurements, and arm span measurements—an indicator of the maximum height likely to be achieved—of 1,145 men and 1,653 women in four cities across the U.S. from 1992 to 1999. The researchers found that each one-inch (2.5-centimeter) increase in knee height cuts a woman's risk of developing dementia by 16 percent (and Alzheimer's disease, in particular, by 22 percent). For each one-inch increase in arm span, the figures were 7 percent and 10 percent, respectively. Men showed a similar, if smaller, advantage. Huang admits she's not sure of the reason for the gender difference but speculates that "maybe there's a difference in optimal diet between men and women."

The study also found that the longer-limbed participants enjoyed "more years of education, increasing satisfaction with one's health," and, especially for women, higher income, thanks again to that early childhood nutrition, Huang says.

Diminutive people can find plenty of other scientific reading matter to make them feel—er—lower. A classic study by two University of Pittsburgh professors in 1990, for instance, reported that people in management positions were "significantly" taller than their underlings. In the 46 presidential elections where the height of both candidates is known, the taller contender won 27 times—a pattern that was repeated this November when the six-foot-one-inch (185-centimeter) Barack Obama defeated the five-foot-seven-inch (170-centimeter) John McCain.

Even a late growth spurt may not help. In 2004 two economics professors from the University of Pennsylvania and another from the University of Michigan at Ann Arbor analyzed height and salary data at various ages for about 10,000 American and British men born between 1958 and 1965. Using

a regression analysis, they discovered that if two adults were the same height, the one who was taller as a teenager earned more—about 1.5 percent to 2 percent more per inch.

In this case, Daniel Silverman of Michigan, one of the report's authors, doesn't blame nutrition. Rather, he blames high school clubs.

"We see some evidence that these [taller] folk have access to social activities as teenagers that shorter kids didn't, where you might obtain social skills," Silverman says, citing student government, sports teams and yearbook staff.

So, should shorter people harbor any high hopes?

"There are a lot of different things that you can do in your life that make you less vulnerable to dementia and Alzheimer's"—such as a healthy diet, exercise, social interactions and continual mental challenges—"regardless of how tall you are," Huang says.

Also, some shorter people possess a rare genetic mutation, known as the "Methuselah gene," that seems to extend their life spans. This defect affects the way their cells use the hormone insulinlike growth factor 1. IGF1 plays a key role in childhood growth—and, more controversially, is touted by athletes and anti-aging proponents as a miracle cure that can help bulk up muscle, inhibit programmed cell death, and reduce body fat.

And smaller women have known since 1995 that they have a medical advantage in one area: According to a study published in *The New England Journal of Medicine*, older "women who were tall when they were young have a greater risk of hip fracture." Why? As the study astutely suggests, "perhaps because they fall further."

--Originally published: Scientific American Online November 14, 2008.

Circumcision Helps Prevent HIV Infection

by Barbara Juncosa

The male foreskin—an unassuming flap of skin eagerly discarded in some cultures—has taken center stage in recent debates over HIV prevention. Although researchers now agree that its removal is a proved method to reduce HIV spread in heterosexual men, the picture for homosexual men remains a bit foggy.

In the late 1980s observations of heterosexual men in Africa indicated that those who had been circumcised might be at less risk of contracting HIV than men who left their foreskins intact. To definitely test the hypothesis, researchers initiated clinical trials in at-risk populations with low rates of circumcision.

Two studies focused on young urban men (ages 18 to 24) in Kenya and South Africa, whereas a third concentrated on a larger cross-section of rural men (ages 15 to 49) in Uganda. Over 11,000 men volunteered for the trials with one group receiving circumcision on enrollment and a control group delaying surgery until the end of the study.

By tracking newly acquired infections in both groups, investigators discovered that circumcision cut HIV transmission rates by 55 to 65 percent. In fact, all three trials were stopped early due to the overwhelming evidence of circumcision's protective effect.

"It was striking that the trials were in very different settings, but yielded consistent results," says Ronald Gray, study leader for the Uganda trial and epidemiologist at Johns Hopkins Bloomberg School of Public Health in Baltimore. "This was the largest protective effect ever seen next to condom use," adds Sten Vermund, director of the Institute for Global Health at Vanderbilt University School of Medicine in Nashville, Tenn. But the question remained: Why?

Microscopic examination of the foreskin yielded important clues for unraveling the benefits of circumcision. Normally, the skin provides a thick protective barrier stemming from keratin—a tough structural protein also found in hair and fingernails. But on the inner surface of the foreskin, the keratin layer is much thinner, resembling the inner lining of the mouth or eyelid more than the palm of the hand.

In uncircumcised men Langerhans cells—immune cells that are primary targets for HIV transmission—"are more richly concentrated near the surface of the foreskin," says Anthony Fauci, director of the U.S. National Institute of Allergy and Infectious Diseases in Bethesda, Md. Without the keratin barrier, HIV can easily access these cells in the foreskin. Following infection, Langerhans cells not only serve as reservoirs for replicating virus, but also transport the virus to nearby lymph nodes where HIV spreads to other immune cells.

In fact, the foreskin's anatomical function actually amplifies the risks. In uncircumcised men the foreskin covers and protects the tip of the penis, paradoxically making the skin there more delicate and prone to microscopic abrasions. These tiny injuries promote inflammation, Fauci says, allowing the virus to come into closer contact with target immune cells. The moist environment that forms under the foreskin also enhances the growth of microbes on the penis's tip, Fauci adds, further

stimulating immune responses near the skin's surface.

At the very least, Vermund notes, the foreskin increases contact time with the virus following unprotected sexual intercourse when infectious fluid becomes trapped.

Although the benefits and efficacy of circumcision are now well documented for heterosexual men, the role of foreskin removal in homosexual men remains an open question. To date, no clinical trial has been conducted to assess if circumcision may be protective for this population. But researchers recently combined the results of 15 observational studies in a meta-analysis conducted in the U.S., Europe and several developing nations involving over 53,000 homosexual men to determine if any evidence for protection exists.

Mathematical analyses indicated that HIV risk was reduced by 14 percent in circumcised homosexual men across the studies, but "the results were not statistically significant, pointing to the possibility that circumcision may not have a substantial effect on HIV infection in men who have sex with men," says Gregorio Millett, study author and a behavioral scientist at the U.S. Centers for Disease Control and Prevention in Atlanta.

The difficulty in evaluating circumcision for homosexual populations, notes Gray, is that most studies do not carefully evaluate sexual practices. Although foreskin removal protects men engaged in anal intercourse (in the same manner as it benefits heterosexual men), "nothing about circumcision protects receptive men as the rectal area is exposed to HIV," Vermund says. The issue will likely remain unresolved until more data can be gathered from studies specifically designed to address the effects of circumcision on the various subgroups of homosexual men.

Current recommendations from the World Health Organization (WHO) in Geneva, Switzerland, call for large-scale circumcision campaigns in countries with high infection rates. For sub-Saharan Africa (where heterosexual sex is primarily responsible for the HIV epidemic), circumcision has the potential to dramatically reduce the toll of the virus, which WHO estimates of up to 5.7 million new infections and three million deaths averted over the next 20 years.

Fauci does not foresee a broad mandate for circumcising infants in the U.S., however, where the practice is already common. "Although circumcision could be beneficial," he says, "HIV is not a disease of the general population here."

Despite the protective effect of circumcision, condoms remain a key component of HIV prevention, because there is "no surgical way to remove all of the inner foreskin," cautions Roger Short, a reproductive biologist at the University of Melbourne in Australia.

In the future, alternatives to circumcision may become available for those men with social or religious objections to the practice. Estrogen creams have recently been proposed as their application sparks a rapid deposition of keratin in the foreskin. If the foreskin can be sufficiently reinforced with keratin to provide a barrier for the Langerhans cells, Short says, a weekly topical application of estrogen could augment or even replace circumcision. For now, however, researchers remain skeptical, as estrogen may also increase the number of HIV receptors on the surface of target cells.

The bottom line: circumcision protects heterosexual men from HIV acquisition via sexual intercourse with the greatest benefits accruing in developing nations that are hardest hit by the

epidemic.

--Originally published: Scientific American Online December 1, 2008.

Underwire Bras Can Cause Cancer

by S. M. Kramer

Sometimes they lift. Sometimes they separate. But do underwire bras cause cancer? Could it be that the very garment designed to offer women support is actually killing them? That's the rumor that has been circulating for decades.

It all began in 1995 with a book called *Dressed to Kill*, in which Sydney Ross Singer and Soma Grismaijer, a husband and wife medical anthropologist team, claimed that women who wore tight-fitting bras all day, every day, had a much higher risk of developing breast cancer than those who went au naturel. The authors claimed that by inhibiting lymphatic drainage, bras trapped toxins in the breast tissue, which caused cancer.

According to critics, however, the bra-caused breast cancer theory is not supported by sufficient evidence. Scientists say the research of Singer and Grismaijer failed to exclude confounding variables such as the presence in some women of known risk factors for breast cancer. Thus, the notion of a correlation between wearing a bra and breast cancer does not appear to hold up.

"It just really is not logical in terms of what would increase your risk of breast cancer," says Louise Brinton, chief of the hormonal and reproductive epidemiology branch of the National Cancer Institute. Brinton, who has been doing research in the field for 30 years, says commonly accepted breast cancer risk factors are generally things that affect endogenous hormone levels.

These risk factors include how old a woman is and the age at which she had her first child. (The risk increases for women who have not had children, or who have given birth after the age of 30.) Breast-feeding and exercise are thought to lower risk, whereas a family history of the disease increases it. Scientists also know that 5 to 10 percent of breast cancers are linked to *BRCA1* and *BRCA2* gene mutations.

Marisa Weiss attributes some of the persistence of this urban legend to how frightening the reality of breast cancer can be. As president and founder of the Narberth, Pa.-based nonprofit Web site *breastcancer.org*, Weiss, who has been in the field for two decades, sees women trying to figure out what in their everyday lives could cause the disease.

Weiss says that although the idea of having one's breasts in cages with metal wires "impeding fluid and marinating breast tissue in toxic liquid" sounds like a reasonable explanation for cancer, it is not. In fact, as she points out, far from being trapped, bodily fluid actually travels up and out of the armpits, not down toward the underwire.

Susan Love is president and medical director of the Dr. Susan Love Research Foundation in Pacific Palisades, Calif., and a former breast cancer surgeon as well as author of *Dr. Susan Love's Breast Book*, now in its fourth edition. Love agrees that the bra myth comes from the frustration of not knowing what causes the disease, coupled with a desire that the disease should come from the outside, from something a woman can control.

"You find people less wanting to think about birth control pills, hormone replacement therapy and

fertility drugs," she says, "and more about pesticides, bras and deodorant. We don't know what causes breast cancer, and the majority of the risk factors that we know about do not explain it. However," she adds, "I don't think bras—or the lack thereof—are the secret answer."

--Originally published: Scientific American Online April 19, 2007.

Cell Phones Can Cause Brain Cancer

by Melinda Wenner

In 2008, Ronald Herberman, director of the University of Pittsburgh Cancer Institute, sent a memo to staffers warning them to limit their cell phone use and to use hands-free sets in the wake of "growing evidence that we should reduce exposure" to cell phone radiation. Among the possible consequences: an increased risk of brain cancer.

Five months later, a top official at the National Cancer Institute (NCI) told a congressional panel that published scientific data indicates cell phones are safe.

So what's the deal? Do cell phones cause cancer—or not?

It depends on whom you ask: Herberman, Robert Hoover, director of NCI's Epidemiology and Biostatistics Program, and other health officials clashed during a hearing before the House Subcommittee on Domestic Policy held to determine whether mobile phones are safe.

"Long term and frequent use of cell phones which receive and emit radio frequency may be associated with an increased risk of brain tumors," Herberman told lawmakers. "I find the old adage 'better to be safe than sorry' to be very apt to this situation."

Hoover, on the other hand, insisted that the pervasive technology was safe, testifying that "its effect on the body appears to be insufficient to cause genetic damage."

The debate became so heated at one point that Rep. Dennis Kucinich (D–Ohio), who called the hearing, snapped at Hoover for interrupting David Carpenter, director of the Institute for Health and the Environment at the University at Albany, State University of New York, as he argued there was enough evidence to warrant more scrutiny and a government warning of potential damage.

Cell phones use non-ionizing radiation, which differs from the ionizing radiation of x-rays and radioactive material in that it does not have enough energy to knock around—or ionize—electrons or particles in atoms. Cell phone radiation falls into the same band of nonionizing radio frequency as microwaves used to heat or cook food. But Jorn Olsen, chair of epidemiology at the University of California, Los Angeles, School of Public Health says that unlike microwaves, cell phones do not release enough radiation or energy to damage DNA or genetic material, which can lead to cancer.

Recent research suggests, however, that although short-term exposure is harmless, long-term cell phone use may be a different story. Three studies since 1999 indicate that people who have used cell phones for more than a decade may have as much as three times greater risk of developing brain tumors on the side of the head against which they most often hold their phone—an argument for, at the least, shifting ears regularly or, even better, using an earpiece or the speakerphone feature while chatting.

"For people who've used their cell phones for more than 10 years and who use their phone on the same side as the tumor, it appears there's an association," Lawrie Challis, emeritus physics professor at the University of Nottingham in England and former chairman of the U.K.'s Mobile

Telecommunications and Health Research program, told ScientificAmerican.com.

Worldwide, one in 29,000 men and one in 38,000 women on average develop brain tumors each year, with people in industrial nations twice as likely as those in developing countries to be diagnosed with one, according to the World Health Organization's International Agency for Research on Cancer (IARC) in Lyon, France. If cell phone use does, in fact, triple the odds of getting cancer, these stats would suggest that over 60 years a man's risk of developing a brain tumor from cell phone use increases from 0.206 percent to 0.621 percent, and a woman's from 0.156 percent to 0.468 percent.

IARC in 2000 launched a study called Interphone, funded by the European Union, the International Union against Cancer and other national and local funding bodies. Interphone compared surveyed cell phone use in 6,420 people with brain tumors to that of 7,658 healthy people in 13 developed countries—Australia, Canada, Denmark, Finland, France, Germany, Israel, Italy, Japan, New Zealand, Norway, Sweden and the U.K.—to try to determine whether people with brain tumors had used their cell phones more than healthy people, an association that might suggest that cell phones caused the tumors.

The results showed no increased risk for brain tumors in mobile phone users. "The interpretation of the results is not simple because of a number of potential biases which can affect the results," says project leader Elisabeth Cardis, a professor at the Center for Research in Environmental Epidemiology at the Barcelona Biomedical Research Park. "These analyses are complex and have, unfortunately, taken much time." Among factors that might skew the results: failure of participants—especially those with tumors—to accurately recall exactly how long and often they talk on their cell phones.

According to the U.S. Centers for Disease Control and Prevention (CDC), the average time between first exposure to a cancer-causing agent and clinical recognition of the disease is 15 to 20 years or longer—and cell phone use in the U.S. has only been popular for a little over a decade. (In 1996 there were 34 million U.S. cell phone users compared with more than 200 million today, according to CTIA–The Wireless Association, a Washington, D.C.–based cell phone industry group.)

Carpenter told the congressional panel that most of the studies that have shown an increased risk are from Scandinavia, where cell phones have been popular since the early 1990s. Herberman added that most of the research showing cell phones are safe is based on surveys of consumers who have used them for less than 10 years.

Despite a dearth of human studies, more than 400 experiments have been done since the early 1970s to determine how cell phone radiation affects animals, cells and DNA. They, too, have produced conflicting results. Some suggest that cell phone radiation damages DNA and/or nerve cells, others do not. At the hearing, Carpenter suggested that cell phones may increase the brain's production of reactive forms of oxygen called free radicals, which can interact with and damage DNA.

Contradictory findings could be a sign of poor study quality, according to NCI expert Hoover. But Jerry Phillips, a biochemist who performed cell phone research at U.S. Department of Veterans Affairs's Pettis VA Medical Center in Loma Linda, Calif., in the 1990s, believes that conflicting results are to be expected given the nature of the radiation being scrutinized.

Phillips says, for instance, that sometimes the body will respond to radiation by initiating a series of intrinsic repair mechanisms designed to fix the harmful effects. In other words, the effects from radiation exposure may be different in different people. And these varied responses may help explain the contradictory results, says Phillips, who is now director of the Science/Health Science Learning Center at the University of Colorado at Colorado Springs.

There is plenty of anecdotal evidence out there claiming a link between cell phone use and cancer: Keith Black, chairman of neurosurgery at Cedars-Sinai Medical Center in Los Angeles, says that the brain cancer (malignant glioma) that killed O. J. Simpson's attorney, Johnnie Cochran, was the result of frequent cell phone use, based on the fact that the tumor developed on the side of the head against which he held his phone. And in May 2008, a week after Massachusetts Sen. Edward Kennedy was diagnosed with a glioma, The EMR Policy Institute, a Marshfield, Vt.–based nonprofit organization that supports research on the effects of electromagnetic radiation, released a statement linking his tumor to heavy cell phone use. But the NCI maintains that there is no definitive evidence that cell phones increase cancer risk.

In other words, the verdict is still out. "We can't rule out the possibility of risk," Nottingham's Challis says. "There hadn't been as much work in this area as is now demanded."

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No Big Toe, No Go

by Corey Binns

During the Vietnam War, young men considered drastic measures to dodge the draft: flee the country, fake an asthma attack or shoot off a big toe. An amputee, according to legionnaire's legend, would be unfit to trudge across rice paddies or move fast to escape enemy fire.

Even today, missing a big toe will disqualify an eager enlistee from the armed forces. The Department of Defense's medical standards require rejecting anyone with a "current absence of a foot or any portion thereof." Yet, doctors consider having nine toes a minor impairment that does little to keep soldiers, runners or walkers off their feet.

"If you have your toe amputated, it doesn't mean you'll never run again," says Sheila Dugan, a physiatrist at Rush University Medical Center in Chicago. In fact, with no toes or other bones below the knee, South African sprinter Oscar Pistorius qualified for the 2012 Olympics in London on his carbon fiber prosthetics. Granted, Dugan says, most runners perform best when their bodies are fully intact: A foot and all of its parts is sturdy enough to absorb the high impact of landing on the ground. The big toe carries the most weight of all the toes, bearing about 40 percent of the load. The big toe is also the last part of the foot to push off the ground before taking the next step.

A nine-toed gait is less efficient, slower and shorter, but no less effective. "You're going to look choppier," Dugan says. Although running on fewer toes takes some getting used to, people can modify their style, train their muscles and practice balance exercises to compensate for a lost toe.

From a functional standpoint, amputating a big toe results in little or no disability, according to a study published in *Clinical Orthopaedics and Related Research* and conducted by Roger Mann, past president of the American Orthopaedic Foot and Ankle Society. Mann observed a slight thickening of the skin on the second and third toes of the impaired foot, and the patients wore down their shoes on that side more.

Regardless, the big toe myth has legs. Patients who arrive in foot and ankle surgeon Robert K. Lee's office with horrible infections are less preoccupied with the mundane consequences of thick toes and worn shoes than with their concern that, without a toe, they'll be confined to a wheelchair. Most of his patients have diabetes—the number one cause for lower extremity amputation in the U.S.—and removing an infected toe ensures their safety. "Their biggest fear is that they are not going to walk again," the University of California, Los Angeles, specialist says.

Customizing shoes to fit oddly numbered toes helps patients adjust to their imperfect gait and quickly get back on their feet. "We have several patients who have had all toes amputated and they walk fine," Lee says. "You lose some balance, strength and ability to propulse in gait, but they walk fine as long as they are in appropriate shoes with customized inserts and toe fillers." Except for aesthetic reasons, Lee does not prescribe prosthetic toes. (One patient requested a prosthetic so she could wear open-toed shoes and not have people stare at her feet.)

Although they are unnecessary, prosthetics for big toes have been around for quite a while. An Egyptian woman was outfitted with a wooden toe prosthesis in approximately 1000 B.C., says

Andreas Nerlich, a pathologist at Ludwig Maximilians University of Munich. The wooden toe, described in *The Lancet* in 2000, is the world's oldest example of a prosthetic limb replacement. Scratch marks on its sole, Nerlich says, are evidence that she wore the toe during her lifetime and, unlike other early prosthetics, it was not popped on in preparation for the afterlife. At any rate, she could have run just as well without it.

--Originally published: Scientific American Online May 3, 2007.

Stress Causes Gray Hair

by Coco Ballantyne

Legend has it that Marie Antoinette's hair turned white the night before she was guillotined. Presumably the stress of impending decapitation caused her locks to lose color within hours. Extremely unlikely, scientists say, but stress may play a role in a more gradual graying process.

The first silvery strands usually pop up around age 30 for men and age 35 for women, but graying can begin as early as high school for some and as late as the 50s for others.

Graying begins inside the sunken pits in the scalp called follicles. A typical human head has about 100,000 of these teardrop-shaped cavities, each capable of sprouting several hairs in a lifetime. At the bottom of each follicle is a hair-growing factory where cells work together to assemble colored hair. Keratinocytes (epidermal cells) build the hair from the bottom up, stacking atop one another and eventually dying, leaving behind mostly keratin, a colorless protein that gives hair its texture and strength. (Keratin is also a primary component of nails, the outer layer of skin, animal hooves and claws?even rhinoceros horns.)

As keratinocytes construct hairs, neighboring melanocytes manufacture a pigment called melanin, which is delivered to the keratinocytes in little packages called melanosomes.

Hair melanin comes in two shades—eumelanin (dark brown or black) and pheomelanin (yellow or red)—that combine in different proportions to create a vast array of human hair colors. Hair that has lost most of its melanin is gray; hair that has lost all of this pigment is white.

At any given time, around 80 to 90 percent of the hairs on a person's head are in an active growth phase, which may last anywhere from two to seven years. At the end of this stage, the follicle shrivels, the keratinocytes and melanocytes undergo programmed cell death (apoptosis), and the follicle enters a resting phase, during which the hair falls out.

To begin building a new hair, the follicle factory must be rebuilt. Fresh keratinocytes and melanocytes are recruited from progenitor cells, also called "stem cells," residing at the bottom of the follicle. For unknown reasons, keratinocyte stem cells have a much greater longevity than the melanocyte stem cells, says David Fisher, professor of pediatrics at Harvard Medical School. "It's the gradual depletion of [melanocyte] stem cells that leads to the loss of pigment," he says.

Does stress accelerate this demise of the melanocyte population? "It is not so simple," Fisher says, noting that the process of graying is a multivariable equation. Stress hormones may impact the survival and / or activity of melanocytes, but no clear link has been found between stress and gray hair.

Suspicions—and hypotheses—abound, however. "Graying could be a result of chronic free radical damage," says Ralf Paus, professor of dermatology at the University Hospital Schleswig-Holstein in Lübeck, Germany. Stress hormones produced either systemically or locally (by cells in the follicle) could produce inflammation that drives the production of free radicals—unstable molecules that damage cells—and "it is possible that these free radicals could influence melanin production or

induce bleaching of melanin," Paus says.

"There is evidence that local expression of stress hormones mediate the signals instructing melanocytes to deliver melanin to keratinocytes," notes Jennifer Lin, a dermatologist who conducts molecular biology research at the Dana-Farber / Harvard Cancer Center in Boston. "Conceivably, if that signal is disrupted, melanin will not deliver pigment to your hair."

And general practice physicians have observed accelerated graying among patients under stress, says Tyler Cymet, head of family medicine at Sinai Hospital in Baltimore, who conducted a small retrospective study on hair graying among patients at Sinai. "We've seen that people who are stressed two to three years report that they turn gray sooner," he says.

Cymet suspects that going gray is "genetically outlined, but stress and lifestyle give you variation of plus or minus five to 10 years." Blonds often appear to go gray later in life because white strands easily hide in a sea of light hair when in fact those who are likely to have the darkest hair (people of African and Asian ancestry) seem to retain their color longer.

In short, scientists are beginning to gather clues that stress can hasten the graying process, but there is no scientific evidence demonstrating a cause-andeffect relationship.

So what happened to Marie Antoinette? There are at least three possible explanations: She may have suffered from sudden onset of the rare autoimmune disease alopecia areata, which attacks pigmented hairs, causing them to fall out, leaving the white (nonpigmented) strands behind. Or the stress of the situation could have generated a swarm of free radicals in her hair follicles, which traveled along the hair shafts, destroying pigment and creating a bleaching effect. Or maybe she just stopped wearing her wigs—revealing she had gray hair all along.

--Originally published: Scientific American Online October 24, 2007.

Chewing Gum Takes Seven Years to Digest

by John Matson

It's a moment nearly everyone has experienced. You're contentedly chewing a wad of gum when an unforeseen turn brings about a quick disposal—the hard way. Whether the cause is imminent detection by a high school teacher, a dearth of garbage cans or even an untimely hiccup, you gulp down the rubbery gob whole. It's only then that a refrain from childhood echoes through your mind: "Don't swallow chewing gum—it will stay in your system for seven years!" As the minty mass descends into your digestive abyss, you wonder: "Will I really be part Wrigley for years to come?"

Rest assured—this decades-old bit of folklore, of unknown origin but almost universal renown, has little basis in fact. Asked if the rumor is medically unfounded, pediatric gastroenterologist David Milov of the Nemours Children's Clinic in Orlando, Fla., replies: "I can tell you that with complete certainty."

If the legend were true, Milov says, "that would mean that every single person who ever swallowed gum within the last seven years would have evidence of the gum in the digestive tract," but colonoscopies and capsule endoscopy procedures turn up no such evidence. "On occasion we'll see a piece of swallowed gum," he says, "but usually it's not something that's any more than a week old."

According to Rodger Liddle, a gastroenterologist at the Duke University School of Medicine, "nothing would reside that long, unless it was so large it couldn't get out of the stomach or it was trapped in the intestine." To put that size into perspective, Liddle says that swallowed quarters usually pass, but that larger coins or objects might not.

So what *does* become of gum that's been chewed up but not spit out? Not much, as it happens. Some of the components, such as sweeteners, are broken down, but the gum's base is largely indigestible. The Food and Drug Administration defines chewing gum base as a "nonnutritive masticatory substance" that may be composed of any number of natural or synthetic elastomers, or rubberlike materials, as well as plasticizing softeners, resins and preservative antioxidizing agents. The permitted elastomers include natural, tree-derived chicle, a gum chewed by indigenous Central Americans, and the somewhat less traditional butyl rubber, which also finds use in the manufacture of inner tubes.

Chewing gum, of course, has been around in one form or another for thousands of years: tooth-marked lumps of birch bark tar have been found in Europe that date back to the Mesolithic period of the Stone Age. And this past summer, researchers reported that quids—balls of plant material chewed by ancient Native Americans—had yielded DNA from members of a tribe called the Western Basketmakers, who lived in the southwestern U.S. some 2,000 years ago.

Unsurprisingly, perhaps, the human body cannot do much with these rubbery concoctions, resilient as they are. Chewing gum "is pretty immune to the digestive process," Milov says. "It probably passes through slower than most foodstuffs, but eventually the normal housekeeping waves in the digestive tract will sort of push it through, and it will come out pretty unmolested."

Nevertheless, the usually safe passage of gum through the system doesn't mean it is wise to

habitually swallow it. As Milov and his colleagues wrote in *Pediatrics* in 1998, chronic gum swallowing—or swallowing gum in conjunction with other indigestibles—can spell trouble. The team's report describes three children suffering from gum-based gastrointestinal blockages, two of whom received gum as positive reinforcement for good behavior and regularly disposed of the treat by swallowing it. In both cases the children became constipated, as the gum snowballed into a substantial "taffylike" mass that required extraction. In the third patient, a girl just a year and a half old, four coins were found lodged in the esophagus, fused into a single blob by a wad of chewing gum.

"I've had another case that was really interesting," Milov adds, "and that was somebody who swallowed sunflower seeds—[and] also, the shells." Upon examining the patient's lower digestive tract, Milov found "all these very prickly seeds that were congealed around gum," forming a body that he describes as "like a porcupine."

Whereas the real (if remote) prospect of an internal quilling ought to be enough to discourage anyone from regularly swallowing gum, the mythical seven-year deterrent persists. Because it causes no real harm, and in fact probably serves to prevent many cases like those Milov describes, the urban legend seems likely to stick around for the foreseeable future. Unlike, thankfully, that wad of spearmint gum you swallowed in high school.

--Originally published: Scientific American Online October 11, 2007.

Opera Singers Can Shatter Glass

by Karen Schrock

The orchestra crescendos as a woman of ample proportions strides to the front of the stage, blonde braids trailing from under a horned helmet. Her gilded bosom heaves as she inhales, opens her lipsticked maw and lets loose an earthshaking high note. Champagne flutes shatter, monocles crack and the chandelier explodes as the power of her voice wreaks havoc on the concert hall. The scene is in countless cartoons and comedies, but is this parody based on reality? Can an opera singer really shatter glass?

Physics suggests that a voice should be able to break glass. Every piece of glass has a natural resonant frequency—the speed at which it will vibrate if bumped or otherwise disturbed by some stimulus, such as a sound wave—as does every other material on Earth. Glass wine goblets are especially resonant because of their hollow tubular shape, which is why they make a pleasant ringing sound when clinked. If a person sings the same tone as that ringing note—a high C in legend but in reality the matching pitch could be any note—the sound of her voice will vibrate the air molecules around the glass at its resonant frequency, causing the glass to start vibrating as well. And if she sings loudly enough, the glass will vibrate itself to smithereens.

"It's possible, but you have to be both good and lucky," says Jeffrey Kysar, a mechanical engineer at Columbia University who studies the different ways in which materials can fracture and fail. "Even if you could excite the cup, that doesn't guarantee it would break. Fracture depends on the size of the initial defects." So in order for a diva to successfully demolish a wine glass, she would have to fortuitously choose one with microscopic defects that are big enough to buckle under pressure.

Invisible cracks and chinks cover every material's surface but their size and location can vary wildly, according to Kysar. Wine glasses that look identical to the naked eye could have radically different fracture strengths, enabling some to withstand much higher levels of volume than others.

Volume is a key player in the glass shattering game, because the loudness of a sound is directly related to the extent it displaces air molecules. In essence, the sound passes from molecule to molecule until it hits the glass. As Brunhilde sings louder, she is, in effect, pushing air at the glass harder. The effect is much like pushing a kid on a swing—the harder each shove, the sooner the kid will go over the top. But a strong shove has little effect unless it is timed so it matches the natural oscillation of the swing—just as a hopeful glass breaker must sing a note that matches the glass's resonant frequency.

The physics involved in the art of vocal destruction seem straightforward enough. But although stories of powerful singers shattering wine goblets, vases and eyeglasses abound, real instances of this feat are suspiciously missing from the historical record. The famous tenor Enrico Caruso was said to have had the ability, but after he died his wife denied these rumors. What gives?

It turns out that most pieces of glass, including most wine glasses, are the equivalent of a kid on a swing who weighs hundreds of pounds. Push away, but that baby probably won't get anywhere close to the top.

Only the finest leaded crystal is dainty and resonant enough to break at volumes that some people can produce without amplification—upward of 100 decibels. A famous commercial from the 1970s showed Ella Fitzgerald shattering a wine glass with ease through Memorex speakers, and the trick has been repeated many times with amplification. The principle of directing sound at a brittle object is used, for example, to break up kidney stones—except doctors don't bother to find the resonant frequency, preferring just to blast the stone with lots of sound energy (and if a singer were as loud as, say, an explosion, she wouldn't have to find the resonant frequency to break a glass, either). Yet, it seems that until recently there was no proof that any person had ever broken glass with his or her voice alone.

Then in 2005 the Discovery Channel television show *MythBusters* tackled the question, recruiting rock singer and vocal coach Jamie Vendera to hit some crystal ware with his best shot. He tried 12 wine glasses before stumbling on the lucky one that splintered at the blast of his mighty pipes. For the first time, proof that an unassisted voice can indeed shatter glass was captured on video.

Vendera's glass-breaking wail registered at 105 decibels—almost as loud as a jackhammer. Not many people can muster the lung power for that kind of noise. Opera singers train for years to build up the strength to produce sustained notes at volumes above 100 decibels. (By comparison, typical speech is around 50 decibels.) Although I was trained as an opera singer before becoming a science journalist, I have never personally witnessed the phenomenon or been able to recreate it myself. That's not to say I won't try again—but perhaps I should procure a horned helmet, gilded breastplate and, most importantly, good amplifying speakers first.

--Originally published: Scientific American Online August 23, 2007.

SECTION 7

Mind and Brain

Half a Brain Is Sometimes Better Than a Whole One

by Charles Q. Choi

The operation known as hemispherectomy—where half the brain is removed—sounds too radical to ever consider, much less perform. In the last century, however, surgeons have performed it hundreds of times for disorders uncontrollable in any other way. Unbelievably, the surgery has no apparent effect on personality or memory.

The first known hemispherectomy was performed on a dog in 1888 by German physiologist Friedrich Goltz. In humans, neurosurgeon Walter Dandy pioneered the operation at Johns Hopkins University in 1923 on a brain tumor patient. (That man lived for more than three years before ultimately succumbing to cancer.) The procedure is among the most drastic kinds of brain surgery —"You can't take more than half. If you take the whole thing, you've got a problem," Johns Hopkins neurologist John Freeman quips.

One side effect Canadian neurosurgeon Kenneth McKenzie reported in 1938 after a hemispherectomy on a 16-year-old girl who suffered a stroke was that her seizures stopped. Nowadays, the surgery is performed on patients who suffer dozens of seizures every day that resist all medication, and which are due to conditions that mostly afflict one hemisphere. "These disorders are often progressive and damage the rest of the brain if not treated," University of California, Los Angeles, neurosurgeon Gary Mathern says. Freeman concurs: "Hemispherectomy is something that one only does when the alternatives are worse."

Anatomical hemispherectomies involve the removal of the entire hemisphere, whereas functional hemispherectomies only take out parts of a hemisphere, as well as severing the corpus callosum, the fiber bundle that connects the two halves of the brain. The evacuated cavity is left empty, filling with cerebrospinal fluid in a day or so.

The strength of anatomical hemispherectomies, a specialty of Hopkins, lies in the fact that "leaving even a little bit of brain behind can lead seizures to return," Freeman says. On the other hand, functional hemispherectomies, which U.C.L.A. surgeons usually perform, lead to less blood loss. "Our patients are usually under two years of age, so they have less blood to lose," Mathern says. Most Hopkins hemispherectomy patients are five to 10 years old.

Neurosurgeons have performed the operation on children as young as three months old. Astonishingly, memory and personality develop normally. A recent study found that 86 percent of the 111 children who underwent hemispherectomy at Hopkins between 1975 and 2001 are either seizure-free or have nondisabling seizures that do not require medication. The patients who still suffer seizures usually have congenital defects or developmental abnormalities, where brain damage is often not confined to just one hemisphere, Freeman explains.

Another study found that children that underwent hemispherectomies often improved academically once their seizures stopped. "One was champion bowler of her class, one was chess champion of his state, and others are in college doing very nicely," Freeman says.

Of course, the operation has its downside: "You can walk, run—some dance or skip—but you lose

use of the hand opposite of the hemisphere that was removed. You have little function in that arm and vision on that side is lost," Freeman says.

Remarkably, few other impacts are seen. If the left side of the brain is taken out, "most people have problems with their speech, but it used to be thought that if you took that side out after age two, you'd never talk again, and we've proven that untrue," Freeman says. "The younger a person is when they undergo hemispherectomy, the less disability you have in talking. Where on the right side of the brain speech is transferred to and what it displaces is something nobody has really worked out."

Mathern and his colleagues have recently conducted the first functional magnetic resonance imaging study into hemispherectomy patients, investigating how their brain changes with physical rehabilitation. Probing how the remaining cerebral hemispheres of these patients acquire language, sensory, motor and other functions "could shed a great deal of light on the brain's plasticity, or ability to change," Freeman notes. Still, having half a brain—and therefore only the use of one hand and half a field of vision in each eye—is a condition most would prefer to avoid.

--Originally published: Scientific American Online May 24, 2007.

The Bigger the Brain, the Smarter You Are

by Kayt Sukel

Research has shown that lead kills neurons (nerve cells), resulting in smaller brains. It has long been hypothesized that such changes in the brain caused by childhood lead exposure may be behind a higher incidence of poor cognitive performance and criminal behavior. And although it is difficult to disentangle the confounding effects of race, class and economics, a recent study by Kim Dietrich, a professor of environmental health at the University of Cincinnati, found that individuals who suffered from the highest lead exposure as children had the smallest brain sizes—as well as the most arrests.

"That early lead exposure was associated with smaller volumes of cortical gray matter [the parts of the brain rich in neural cell bodies and synapses] in the prefrontal area," he says. "And the fact that we saw both criminal behavior and volume loss in this critical area for executive function is probably more than just a coincidence."

That may be so, however, new scientific studies across several animal species, including humans, are challenging the notion that brain size alone is a measure of intelligence. Rather, scientists now argue, it is a brain's underlying organization and molecular activity at its synapses (the communication junctions between neurons through which nerve impulses pass) that dictate intelligence.

Two years ago, Paul Manger, a professor of health sciences at the University of the Witwatersrand in Johannesburg, South Africa, caused quite a stir when he referred to the beloved bottlenose dolphin, owner of a large, nearly human-size brain, as "dumber than a goldfish."

"When you look at cetaceans, they have big brains, absolutely," Manger says. "But if you look at the actual structure of the brain, it's not very complex. And brain size only matters if the rest of the brain is organized properly to facilitate information processing."

He argues that the systems within the brain—how neurons or nerve cells and synapses are organized—are the keys to determining information-processing capacity. Manger speculates that cetacean brains are large not because of intelligence but instead due to an abundance of fatty glial cells (non-nerve cells serving as a supporting tissue), which may be present to provide warmth in cold waters for the information-processing neurons in the brain's interior.

Mark Uhen, a vertebrate paleontologist at the Alabama Museum of Natural History, and Lori Marino, a biologist who studies brain evolution of cetaceans and primates at Emory University's Yerkes National Primate Research Center, disagree. Marino says that Manger's theories discount years of behavioral evidence that show dolphins to be complex thinkers. What's more, she says, the mammals have an unusual brain structure with a different functional map and therefore cannot be compared with other species.

Marino believes that the dolphin's unique brain organization may represent an alternate evolutionary route to complex intelligence—and that molecules released in synapses may provide that alternative path.

A study published in *Nature Neuroscience* by Seth Grant, a neuroscientist at the Wellcome Trust

Sanger Institute in Cambridge, along with Richard Emes, a professor in Bioinformatics at Keele University School of Medicine in North Staffordshire, both in England, suggests that all species have the same basic proteins that act in the synapses.

"If you look at us and fish, we have very different cognitive abilities," Emes says. "But we have roughly the same number of these synaptic proteins. It is the number of interactions and gene duplications of these proteins that provide the brain building blocks for higher level cognitive function."

Emes, Grant and colleagues agree with Marino and Uhenthat intelligence and differences between species are due to molecular complexity at the synaptic level. "The basic dogma says that the computational properties of the brain are based on the number of neurons and synapses," Grant says. "But we modify that by saying that the molecular complexity within those synapses is also important."

Grant and Emes looked at where approximately 150 synaptic proteins were released in the nervous systems of yeast, fruit flies and mice. They found that a variation in production and distribution patterns was linked to higher-level brain organization.

"The proteins that you find in yeast are the sort of proteins that are far more likely to be found expressed throughout the brain in uniform quantities," Grant says. "They laid a foundation to make more diverse and different regions of the brain using different combinations and expressions of other, more innovative proteins." He likens these molecular proteins to implements in a toolbox that help to build specialized brain regions. He goes on to say that the different interactions, duplications or deletions of these proteins resulted over time in the evolutionary development of regions like the prefrontal cortex in humans which is involved in higher executive function like planning and goal-directed behavior

Grant says that this finding offers scientists a new way to approach the study of brain evolution and intelligence and, perhaps more importantly, suggests that looking at sheer brain size has very little to offer in understanding cognitive abilities.

"It's clear now that there are wonderful mental abilities in birds even with their relatively small brains, nerve cells and neural connections. But they have complex molecular synapses," says Grant. "My sense is in the next 10 to 20 years our perspectives about the mental capacities of different species will change quite radically."

But the idea that a big brain equals big smarts is not going to go away anytime soon. Though Manger discounts the role of glial cells in intelligence, a posthumous anatomical study of Albert Einstein's brain showed that the scientific genius's brain differed from the brains of other dead scientists only with its greater ratio of glial cells to neurons. But a study of Einstein's brain organization and synaptic molecule configuration still remains to be completed.

--Originally published: Scientific American Online April 14, 2009.

Spring Fever Is a Real Phenomenon

by Christie Nicholson

There's an illness that has been documented by poets for centuries. Its symptoms include a flushed face, increased heart rate, appetite loss, restlessness and daydreaming. It's spring fever, that wonderfully amorphous disease we all recognize come April and May.

"Spring fever is not a definitive diagnostic category," says Michael Terman, director of the Center for Light Treatment and Biological Rhythms at Columbia University Medical Center. "But I would say it begins as a rapid and yet unpredictable fluctuating mood and energy state that contrasts with the relative low [of the] winter months that precede it."

Such spring fever remains a fuzzy medical category, but there has been a great deal of research on how seasonal changes affect our mood and behavior. Matthew Keller, postdoctoral fellow at the Virginia Institute for Psychiatric and Behavioral Genetics in Richmond, studied 500 people in the U.S. and Canada and found that the more time people spent outside on a sunny spring day the better their mood. Such good moods decreased during the hotter summer months and there is an optimal temperature for them, Keller claims: 72 degrees Fahrenheit, otherwise known as room temperature.

Of course, spring doesn't just lighten our mood; as Alfred Lord Tennyson described, "In the spring a young man's fancy lightly turns to thoughts of love." Studies show that sexual behavior in mammals follows a seasonal pattern, one that promotes survival. In fact, researchers discovered that birth spikes in field mice are more significant the farther the mice are from the equator, as seasons become more pronounced. The same trend was also seen in hares and deer, according to *Mammalian Reproductive Biology* by biologist Frank Bronson of the University of Texas. It is well documented that animals and humans track seasons by measuring the length of days through an internal biological clock, and this is what controls their breeding.

The biological clock, called the suprachiasmatic nucleus (SCN), sits in mammals' hypothalamus. It monitors light through a pathway to the retina and conveys information about day length to the pineal gland. This pea-size gland, tucked at the base of the cerebrum, controls the secretion of melatonin, dubbed the sleep hormone because it is only released in the dark or in dim light. The duration of melatonin release changes with nocturnal length, which is longest during winter. And it has been thought that our increased energy in the spring months is somehow linked to the decreased duration of melatonin production, due to shorter nights.

"From a biological perspective, most types of animals, and maybe even plants, have seasonal variation in behavior and physiology; there are seasonal cycles in human rates of conception," says Thomas Wehr of the National Institute of Mental Health, who reviewed the effect of biological rhythms on reproduction in 2001 for the *Journal of Biological Rhythms*. Historically there have been more births in the spring. In the late 16th century birth rates typically spiked to 20 percent above the average in March—meaning the babies were conceived in June—but over the past 400 years rates have flattened to about 10 percent above the average, according to research done by David Lam at the University of Michigan's Population Studies Center in Ann Arbor.

Cultural and social factors influence conception patterns but biology plays a strong role, as shown by peaks that are 20 percent above average during June—technically the tail end of spring—in the production of reproductive fuel: luteinizing hormone, which produces testosterone in men and triggers ovulation in women. Research also shows that successful in vitro fertilization follows the same seasonal peaks as natural birth. "In humans we don't know for sure what the causal connection is," Wehr says, "but if most other mammals are using changes in day length, then the melatonin signal and conception rates is a pretty plausible relationship, but more research is needed."

The idea that melatonin triggers our mood change in the spring is "too convenient an explanation," Terman counters. "Melatonin is more like the hands of the clock, it's not the essential variable." Since the mid-1980s researchers have focused on the seasonal effect on moods, with the emergence of a diagnostic label for winter depression, seasonal affective disorder (SAD). No one knows the exact cause of SAD, Terman says, but there are distinct patterns of winter depression lifting in the spring. And the key for that rise in mood, he argues, is the earlier onset of morning light. He has shown that there is more depression on the western edges of time zones in the U.S., where the sun rises later.

Clearly, there are marked correlations between moods, behavior and the lengthening days of spring, but the precise cause for our renewed energy remains elusive. The evidence for spring fever remains largely anecdotal. But, just as SAD has proved sadly real, spring fever edges away from science fiction, even if it is not quite science fact.

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Testosterone Alone Does Not Cause Violence

by Christopher Mims

It's commonly assumed that testosterone, that stereotypically male hormone, is intimately tied to violence. The evidence is all around us: weight lifters who overdose on anabolic steroids experience "roid rage," and castration—the removal of the source of testosterone—has been a staple of animal husbandry for centuries.

But what is the nature of that relationship? If you give a normal man a shot of testosterone, will he turn into the Incredible Hulk? And do violent men have higher levels of testosterone than their more docile peers?

"[Historically,] researchers expected an increase in testosterone levels to inevitably lead to more aggression, and this didn't reliably occur," says Frank McAndrew, a professor of psychology at Knox College in Galesburg, Ill. Indeed, the latest research about testosterone and aggression indicates that there's only a weak connection between the two. And when aggression is more narrowly defined as simple physical violence, the connection all but disappears.

"What psychologists and psychiatrists say is that testosterone has a facilitative effect on aggression," comments Melvin Konner, an anthropologist at Emory University and author of *The Tangled Wing: Biological Constraints on the Human Spirit*. "You don't have a push-pull, click-click relationship where you inject testosterone and get aggressiveness."

Castration experiments demonstrate that testosterone is necessary for violence, but other research has shown that testosterone is not, on its own, sufficient. In this way, testosterone is less a perpetrator and more an accomplice—one that's sometimes not too far from the scene of the crime.

For example: regardless of their gender, the most violent prisoners have higher levels of testosterone than their less violent peers. Yet scientists hypothesize that this violence is just one manifestation of the much more biologically and reproductively salient goal of dominance.

"It has been suggested that the antisocial behaviors related to high testosterone are a function of the manner by which dominance is maintained in these groups," says Robert Josephs of the University of Texas at Austin. In other words, if researchers were to study other groups of folks, say the rich and famous, they might discover that testosterone is connected not to violence, but to who drives the biggest SUV or has the nicest lawn. As Josephs put it: "Perhaps slipping a shiv into your neighbor's back might play in the penitentiary, but it probably won't earn you any status points in Grosse Pointe."

One psychologist, James Dabbs of Georgia State University in Atlanta, made a career out of conducting studies connecting testosterone to every kind of lifestyle imaginable. In his book *Heroes, Rogues and Lovers,* he noted that athletes, actors, blue-collar workers and con men tend to have higher levels of testosterone than clerks, intellectuals and administrators.

What Dabbs didn't address was whether this correlation was the cause or an effect of the environment these men found themselves in. Which is to say, are high-testosterone males more likely to become violent criminals, or does being a violent criminal raise a man's level of testosterone?

No one really knows the answer, but a growing body of evidence suggests that testosterone is as much the result of violence as its cause. Indeed, both winning a sporting match and beating an opponent at chess can boost testosterone levels. (On the other hand, losing a sporting match, growing old and becoming obese all reduce levels of testosterone.)

"The causal arrow goes both ways," says Peter Gray of the University of Nevada, Las Vegas, whose own work shows that marriage and fatherhood lower testosterone levels. "There's evidence in humans that, just as in animals, testosterone is responsive to male-male competition."

Changes in testosterone levels in response to challenges can be further shaped by our expectations. In one experiment that put a biological spin on the red state–blue state divide, researchers at the University of Michigan at Ann Arbor had a volunteer "accidentally" bump into and then insult men who were raised either in the North or the South. The researchers hypothesized that Southerners come from a "culture of honor" in which aggressive responses to insults are culturally appropriate, and the results of their experiment bolstered that notion: Not only were Southerners more likely than their northern counterparts to respond with aggression, but their levels of testosterone also rose as a result. The Northerners, in contrast, were much less likely to experience an increase in testosterone.

"From what we can tell now, testosterone is generated to prepare the body to respond to competition and/or challenges to one's status," McAndrew observes. "Any stimulus or event which signals either of these things can trigger an increase in testosterone levels."

It makes sense—in the short-term, testosterone helps make both males and females bigger, stronger and more energetic, all of which would be useful for winning a physical or even mental contest. Testosterone is also responsible for libido in both sexes, and if researchers like Josephs are correct, it powers our drive for social dominance, which is one way that humans decide who gets to mate with whom.

Arguably, the weak correlation between testosterone and violence gives us reason to be optimistic about the human race: Whereas other animals battle over mates as a direct result of their seasonal fluctuations in testosterone and other hormones, humans have discovered other ways to establish pecking orders. Which isn't to say that we can't rapidly adapt to the modern-day manifestations of our violent past: McAndrews's work demonstrated that one surefire way to raise a man's testosterone level is to allow him to handle a gun.

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Less Sleep Means More Dreams

by Christie Nicholson

Some years ago Eva Salem got into some trouble with a crocodile. It snapped her hand in its jaws. In a panic, she managed to knock out the crocodile and free herself. Then, she woke up.

"I imagine that's what it's like when you're on heroin. That's what my dreams were like—vivid, crazy and active," she says. Salem, a new mother, had been breastfeeding her daughter for five months before the croc-attack dream, living on four hours of sleep a night. If she did sleep a full night, her dreams boomeranged, becoming so vivid that she felt like she wasn't sleeping at all.

Dreams are amazingly persistent. Miss a few from lack of sleep and the brain keeps score, forcing payback soon after eyelids close. "Nature's soft nurse," as Shakespeare called sleep, isn't so soft after all.

"When someone is sleep deprived we see greater sleep intensity, meaning greater brain activity during sleep; dreaming is definitely increased and likely more vivid," says neurologist Mark Mahowald of the University of Minnesota and director of the Minnesota Regional Sleep Disorders Center in Minneapolis.

The phenomenon is called REM rebound. REM refers to "rapid eye movement," the darting of the eyes under closed lids. In this state we dream the most and our brain activity eerily resembles that of waking life. Yet, at the same time, our muscles go slack and we lie paralyzed—a toe might wiggle, but essentially we can't move, as if our brain is protecting our bodies from acting out the stories we dream.

Sleep is divided into REM and four stages of non-REM; each has a distinct brain wave frequency. Stage one of non-REM is the nodding off period where one is between sleeping and waking; it's sometimes punctuated with a sensation of falling into a hole. In stage two the brain slows with only a few bursts of activity. Then the brain practically shuts off in stages three and four and shifts into slow-wave sleep, where heart and breathing rates drop dramatically.

Only after 70 minutes of non-REM sleep do we experience our first period of REM, and it lasts only five minutes. A total non-REM– REM cycle is 90 minutes; this pattern repeats about five times over the course of a night. As the night progresses, however, non-REM stages shorten and the REM periods grow, giving us a 40-minute dreamscape just before waking.

The only way scientists can study REM deprivation is by torturous sleep deprivation. "We follow the [electroencephalogram] tracing and then when we see [subjects] moving into REM, we wake them up," says psychologist Tore Nielsen, director of the Dream and Nightmare Lab at the Sacré-Coeur Hospital in Montreal. "As soon as you start to rob them of REM, the pressure for them to go back into REM starts to build." Sometimes Nielsen will have to wake them 40 times in one night because they go directly into REM as soon as they are asleep.

Of course there is non-REM rebound as well, but the brain gives priority to the slow-wave sleep and then to REM, suggesting that the states are independent of each other.

In a 2005 study published in *Sleep*, Nielsen showed that losing 30 minutes of REM one night can lead to a 35 percent REM increase the next night—subjects jumped from 74 minutes of REM to a rebound of 100 minutes.

Nielsen also found that dream intensity increased with REM deprivation. Subjects who were only getting about 25 minutes of REM sleep rated the quality of their dreams between nine and eight on a nine-point scale (one being dull, nine being dynamite).

Of course, REM deprivation, and the subsequent rebound, is common outside the lab. Alcohol and nicotine both repress REM. And blood pressure drugs as well as antidepressants are also well known REM suppressants. (Take away the dreams and, curiously, the depression lifts.) When patients stop the meds, and the vices, they're rewarded with a scary rebound.

But the persistence of REM begs the question: Why is it so insistent? When rats are robbed of REM for four weeks they die (although the cause of death remains unknown). Amazingly, even though we spend about 27 years dreaming over the course of an average life, scientists still can't agree on why it's important.

Psychiatrist Jerry Siegel, head of the Center for Sleep Research at the University of California, Los Angeles, recently proved that REM is nonexistent in some big-brained mammals, such as dolphins and whales. "Dying from lack of REM is totally bogus," Siegel says. "It's never been shown in any species other than a rat."

Some theories suggest that REM helps regulate body temperature and neurotransmitter levels. And there is also evidence that dreaming helps us assimilate memories. Fetuses and babies spend 75 percent of their sleeping time in REM. Then again, platypuses experience more REM than any other animal and researchers wonder why, because, as Minnesota's Mahowald puts it, "Platypuses are stupid. What do they have to consolidate?"

But, given that rats run through dream mazes that precisely match their lab mazes, others feel that there must be some purpose or meaningful information in dreams.

John Antrobus, a retired professor of psychology and sleep research at the City College of New York says that dream content is tied to our anxieties. But he never found the extreme vividness in REM rebound that others assume is there, based on a higher level of brain activity which likely means more action-packed dreams.

"The brain is an interpretive organ, and when regions are less connected as they are in sleep, we get bizarre narratives," he says. "But its purpose? For that we have to ask what is the purpose of thought. We can't answer one without answering the other."

--Originally published: Scientific American Online September 20, 2007.

Waking a Sleepwalker Could Kill Them

by Robynne Boyd

Sleepwalkers do the strangest things. Many accounts attest to a somnambulist leaving their house clad only in underpants, or rising to cook a meal and returning to bed without so much as tasting it. A stern warning is frequently tacked onto these tales: waking a sleepwalker could kill them. The chances of killing a sleepwalker due to the shock of sudden awakening, however, is about as likely as somebody expiring from a dream about dying.

While it is true that waking a sleepwalker, especially forcefully, may distress them, it is an absolutely false statement that someone would die from shock, says Michael Salemi, general manager at the California Center for Sleep Disorders. "You can startle sleepwalkers, and they can be very disoriented when you wake them up and they can have violent, or confused reactions, but I have not heard of a documented case of someone dying from being woken up." Sleepwalking's hazard is more closely linked to what the sleepwalker may encounter when roaming about in a nocturnal reverie.

Sleepwalking, or "somnambulism," is part of a larger category of sleep-related disorders known as parasomnias, which include night terrors, REM behavior disorder, restless legs syndrome and sleepwalking. For the majority of people, sleepwalking consists of mundane activities such as sitting up in bed, ambling around the house or dressing and undressing. A minority of sleepwalkers, however, perform more complex behaviors, including preparing meals, having intercourse, climbing through windows and driving cars—all while actually asleep. These episodes can be as brief as a few seconds or can continue for 30 minutes or longer.

"In sleepwalking you are half asleep and half awake," says Carlos Schenck of the Minnesota Regional Sleep Disorders Center at the University of Minnesota Medical School, "The brain produces delta waves and theta waves, which really demonstrates that the person is in a twilight state." Sleepwalking commonly occurs during the third and fourth stage of non-REM sleep—the deepest stage of sleep—characterized by slow-wave, or delta, sleep and little to no dreaming.

"Children developmentally are much more at risk of sleepwalking," Schenck says. "If a child does sleepwalk, waking up the child 45 minutes after going to sleep can interrupt the cycle. In general, soothing and leading them back to bed is the best way to handle the situation." Up to 17 percent of children have at least one sleepwalking episode. They peak between the ages of 11 and 12 and then decline during adolescence. Though rarer in adults (2.5 percent of the population), episodes could be caused by stress, lack of sleep or irregular sleep.

Still, more disconcerting than the occasional nocturnal stroll is the potential peril caused by sleepwalking. "Sleepwalkers can harm themselves and others, and even kill themselves and others, and they can engage in highly complex behaviors such as driving long distances, and hurt others with sleep aggression and violence," Schenck says. "So there are a number of ways that sleepwalkers can be dangerous to themselves and others during their episodes." For example, he notes, Sandy, a slender female in her teens, tore her bedroom door off the hinges one night. She was unable to replicate that strength when awake. And a young man frantically drove to his parent's house 10 miles away. He woke to the sound of his own fists beating on their front door. In dramatic cases like these,

doctors will prescribe benzodiazepines to ease a patient's nighttime activity.

Typically, though, sleepwalking is a moderate, infrequent occurrence most easily managed by leading a sleepwalker back to bed by the elbow. One final caveat: if spectators are still chuckling about the episode in the morning, they may be alone. Somnambulist's memories snooze through the whole event.

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SECTION 8

Miscellany

Archimedes Coined the Term "Eureka!" in the Bath

by David Biello

Let's begin with the story: the local tyrant contracts the ancient Greek polymath Archimedes to detect fraud in the manufacture of a golden crown. Said tyrant, name of Hiero, suspects his goldsmith of leaving out some measure of gold and replacing it with silver in a wreath dedicated to the gods. Archimedes accepts the challenge and, during a subsequent trip to the public baths, realizes that the more his body sinks into the water, the more water is displaced--making the displaced water an exact measure of his volume. Because gold weighs more than silver, he reasons that a crown mixed with silver would have to be bulkier to reach the same weight as one composed only of gold; therefore it would displace more water than its pure gold counterpart. Realizing he has hit upon a solution, the young Greek math whiz leaps out of the bath and rushes home naked crying "Eureka! Eureka!" Or, translated: "I've found it! I've found it!"

Several millennia later, the scientific world is replete with the exclamation, and many people have received inspiration in the shower. The mathematical conjectures of Henri Poincaré, Einstein's theory of relativity, Newton getting dinged on the head with an apple and discovering gravity--all have been described as eureka moments. Edgar Allan Poe wrote a prose poem to science by that title and the prospectors of California's gold rush were so fond of the phrase that it crept into that state's motto. Even the American Association for the Advancement of Science calls its breaking scientific news site *EurekAlert*.

Too bad, then, that Archimedes probably never uttered the phrase in that way.

First and foremost, Archimedes himself never wrote about this episode, although he spent plenty of time detailing the laws of buoyancy and the lever (prompting him to reputedly pronounce: "Give me a place to stand and I will move the earth"), calculating the ratio of circles we know as pi, and starting along the path to the integral calculus that would not be invented for another 2,000 years, among other mathematical, engineering and physical feats.

The oldest authority for the naked-Archimedes eureka story is Vitruvius, a Roman writer, who included the tale in his introduction to his ninth book of architecture some time in the first century B.C. Because this was nearly 200 years after the event is presumed to have taken place, the story may have been improved in the telling. "Vitruvius may have gotten it wrong," says Chris Rorres, a mathematician at the University of Pennsylvania and a self-described Archimedes "groupie." "The volumetric method works in theory so it sounds right but when you actually try it you find that the real world gets in the way."

In fact, Rorres is one of a long line of scientists, including Galileo, who have read the account and thought "That can't be right." As Galileo showed in his tract *La Bilancetta*, or "The Little Balance," a scientist of Archimedes' stature could have achieved a far more precise result using his own law of buoyancy and an accurate scale, something far more common in the ancient world than a very precise pycnometer, which is used to measure displacement. (The surface tension of water can render the volume of a light object like a wreath unmeasurable.) "There may be some truth to it," Rorres adds. "Archimedes did measure the volume of things but the eureka moment was maybe due to his original

discovery [concerning buoyance], not to sitting in the bathtub and then running through the streets of Syracuse naked."

Much like Newton's apple, the exclamation persists because of the enduring power of the story: a golden crown, a life in the balance, a naked mathematician. Archimedes was a font of both mathematical insight and smart quotes as well as the hero of some really great stories. (One credits him with the invention of the death ray--actually an array of mirrors to focus sunlight--to set fire to an invading Roman fleet.) The suspect foundations of the eureka moment take nothing away from the word's ability to uniquely and concisely convey the flash of inspiration.

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Turning a Wobbly Table Will Make It Steady

by JR Minkel

It's a problem as old as civilization: the wobbly table. You may have thought your only recourse against this scourge is a hastily folded cocktail napkin stuffed under the offending leg. If so, take heart, because mathematicians have recently proved a more elegant solution. Just rotate the table.

The intuitive argument, which dates back at least to a 1973 Scientific American column by Martin Gardner, is straightforward. Consider a square table with four equally long legs. Any three of the legs must be able to rest on the floor simultaneously, as a tripod does. Assume the floor undulates smoothly and the fourth leg hovers above it.

Now imagine turning the table about its center while keeping the first three legs grounded, or balanced. Once the table has rotated by 90 degrees, the wobbly leg must lie below the floor. (If you do not see why, imagine pushing down equally on the wobbly leg and a neighboring leg until the neighbor sinks below the floor and the wobbly leg touches down.) And so, at some point along the wobbly leg's arc, it has to hit a spot on which it can rest. As simple as this argument may sound, however, proof was a long time coming.

The first serious mathematical inroad against table wobbling seems to have occurred in the late 1960s with Roger Fenn, a PhD student at the University of London. One day Fenn and his graduate adviser ended up at a coffee shop faced with—you guessed it—an unsteady table. "The table wouldn't stop wobbling and we fiddled it around until we got it to stop," recalls Fenn, who is now at the University of Sussex.

At his adviser's suggestion, Fenn wrote out a proof that for any smoothly curving floor that bulges upward like a hill, there is at least one way to position the table so that it is balanced and horizontal. But he did not reveal how exactly to find that sweet spot, and he quickly tabled the subject. "I didn't think people were going to take this very seriously," he admits. "You say to somebody you've met, 'Well I'm trying to put a table on the floor so it doesn't wobble'; they'll say, 'Oh yeah?'"

The season for proving the table turning hypothesis would not arrive for another 35 years. By then, the idea had become such a part of mathematical lore that two years ago mathematician Burkard Polster of Monash University in Australia included it in an article on neat math tricks for teachers. He promptly received a letter pointing out that the idea would not work if a floor possessed sheer cliffs, such as between tiles.

Polster rose to the challenge. "It's never been really pinpointed exactly what the ground should be like," he says. So he and some of his colleagues ran through the appropriate calculus and satisfied themselves that if a floor has no spots that slope by more than 35.26 degrees, then turning will indeed balance a square or *rectangular* table, although the table may not end up level. They detail the proof in a paper published by the *Mathematical Intelligencer*. (In one of those odd cases of co-discovery, a retired CERN physicist named André Martin published a similar result within a few months of the Australians' version.)

Polster's group even spells out a procedure for balancing the table. First lift up the leg of the table

diagonal from the wobbly leg. Make sure both legs are roughly equal distances off the ground and then begin rotating. "In practice," the researchers write, "it does not seem to matter how exactly you turn your table on the spot, as long as you turn roughly around the center of the table."

So, next time you feel a table start to tilt, put that napkin down and don't be shy about turning the tables on a wobbly dining experience. Rest assured, mathematics is on your side.

--Originally published: Scientific American Online January 25, 2007.

Infinity Comes in Different Sizes

by John Matson

In the 1995 Pixar film *Toy Story*, the gung ho space action figure Buzz Lightyear tirelessly incants his catchphrase: "To infinity … and beyond!" The joke, of course, is rooted in the perfectly reasonable assumption that infinity is the unsurpassable absolute—that there is no beyond.

That assumption, however, is not entirely sound. As German mathematician Georg Cantor demonstrated in the late 19th century, there exists a variety of infinities—and some are simply larger than others.

Take, for instance, the so-called natural numbers: 1, 2, 3 and so on. These numbers are unbounded, and so the collection, or set, of all the natural numbers is infinite in size. But just how infinite is it? Cantor used an elegant argument to show that the naturals, although infinitely numerous, are actually less numerous than another common family of numbers, the "reals." (This set comprises all numbers that can be represented as a decimal, even if that decimal representation is infinite in length. Hence, 27 is a real number, as is π, or 3.14159…)

In fact, Cantor showed, there are more real numbers packed in between zero and one than there are numbers in the entire range of naturals. He did this by contradiction, logically: He assumes that these infinite sets are the same size, then follows a series of logical steps to find a flaw that undermines that assumption. He reasons that the naturals and this zero-to-one subset of the reals having equally many members implies that the two sets can be put into a one-to-one correspondence. That is, the two sets can be paired so that every element in each set has one—and only one—"partner" in the other set.

Think of it this way: even in the absence of numerical counting, one-to-one correspondences can be used to measure relative sizes. Imagine two crates of unknown sizes, one of apples and one of oranges. Withdrawing one apple and one orange at a time thus partners the two sets into apple-orange pairs. If the contents of the two crates are emptied simultaneously, they are equally numerous; if one crate is exhausted before the other, the one with remaining fruit is more plentiful.

Cantor thus assumes that the naturals and the reals from zero to one have been put into such a correspondence. Every natural number n thus has a real partner r_n. The reals can then be listed in order of their corresponding naturals: r_1, r_2, r_3, and so on.

Then Cantor's wily side begins to show. He creates a real number, called p, by the following rule: make the digit n places after the decimal point in p something other than the digit in that same decimal place in r_n. A simple method would be: choose 3 when the digit in question is 4; otherwise, choose 4.

For demonstration's sake, say the real number pair for the natural number 1 (r_1) is Ted Williams's famed .400 batting average from 1941 (0.40570…), the pair for 2 (r_2) is George W. Bush's share of the popular vote in 2000 (0.47868…) and that of 3 (r_3) is the decimal component of π (0.14159…).

Now create p following Cantor's construction: the digit in the first decimal place should not be equal to that in the first decimal place of r_1, which is 4. Therefore, choose 3, and p begins 0.3… Then

choose the digit in the second decimal place of p so that it does not equal that of the second decimal place of r_2, which is 7 (choose 4; $p = 0.34\ldots$). Finally, choose the digit in the third decimal place of p so that it does not equal that of the corresponding decimal place of r_3, which is 1 (choose 4 again; $p = 0.344\ldots$).

Continuing down the list, this mathematical method (called "diagonalization") generates a real number p between zero and one that, by its construction, differs from every real number on the list in at least one decimal place. Ergo, it cannot be on the list.

In other words, p is a real number without a natural number partner—an apple without an orange. Thus, the one-to-one correspondence between the reals and the naturals fails, as there are simply too many reals—they are "uncountably" numerous—making real infinity somehow larger than natural infinity.

"The idea of being 'larger than' was really a breakthrough," says Stanley Burris, professor emeritus of mathematics at the University of Waterloo in Ontario. "You had this basic arithmetic of infinity, but no one had thought of classifying within infinity—it was just kind of a single object before that."

Adds mathematician Joseph Mileti of Dartmouth College: "When I first heard the result and first saw it, it was definitely something that knocked me over. It's one of those results that's short and sweet and really, really surprising."

--Originally published: Scientific American Online July 19, 2007.

A Spoon in the Bottle Keeps Champagne Bubbly

by John Matson

If you had trouble polishing off any open bottles of sparkling wine on New Year's Eve, you may have employed an old kitchen trick to keep the leftover bubbly...well, bubbly.

The trick is simple: just put a teaspoon, handle down, into the bottle's mouth. Many people have cited anecdotal evidence that the spoon helps keep sparkling wines effervescent in the fridge for a day or more after opening.

There's just one problem. Belief in the spoon tactic, which is of uncertain origin but seems especially prevalent in Europe, appears to be misplaced.

"I think it's a myth," says Stanford University chemist Richard Zare, who undertook an extracurricular investigation of the teaspoon's preservative powers in 1994. Zare, along with food writer and San Francisco Bay Area resident Harold McGee, their wives and other friends, uncorked several bottles of bubbly and refrigerated them for 26 hours under different preservation methods—including some with spoons and some without. Then they sampled and scored the sparkling wines in a blind test. The result: Zare and his fellow testers did not detect any boost in the sparkle of the spooned bottles. A more recent, smaller-scale test on the television show *MythBusters* arrived at a similar conclusion.

Although Zare's study was somewhat informal, he believes the methodology was solid. "Hal McGee had just bought a new refrigerator that had nothing in it," he recalls. "This was great—because it had no smells or anything in it." And the bottles of wine, which all came from the same lot, were kept under identical ambient conditions. "We really tested it quite extensively," Zare says.

What is more, the California test jibes with the results of a similar experiment conducted around the same time by researchers at the Interprofessional Committee of Champagne. The CIVC, as it is known by its French initials, is an association of grape-growers and winemakers in the Champagne region of France that defends the literal geographic meaning of the appellation "champagne"—bubbly from other locations is sparkling wine. "The experiment was done in Épernay, near Reims, with champagne from the same batch, and the pressure was measured in various circumstances, such as opened bottles, opened bottles with spoon, bottle closed with stopper [and] bottle closed with cork (after having been opened)," wrote chemist and food journalist Hervé This in an e-mail; This described the research in his 2006 book, *Molecular Gastronomy*. "The pressure in bottles opened and left open or in bottles opened and left open with a spoon decreased in the same way—whereas a stopper or cork prevented the gas escape," he added.

So if the dangling teaspoon appears to have little to no effect on preserving carbonation, what is a champagne sipper to do with his or her half-empty bottle? No special stopper is needed, says Zare, in whose (admittedly subjective) taste test recorked wine rated poorly. "Keep it cold. In fact, never let it warm up. That's the secret," he says. The reason: in many liquids, including water, carbon dioxide is more soluble at low temperature, so cold liquids better retain their dissolved gas. Some sparkling wines are so saturated with carbon dioxide, Zare says, that they can remain bubbly in the fridge for

days, even without a stopper. “If you keep it cold from the start,” he adds, “it just goes on and on.”

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